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HEALTH TECHNICAL MEMORANDUM

ELECTRICAL SERVICES: SUPPLY AND DISTRIBUTION

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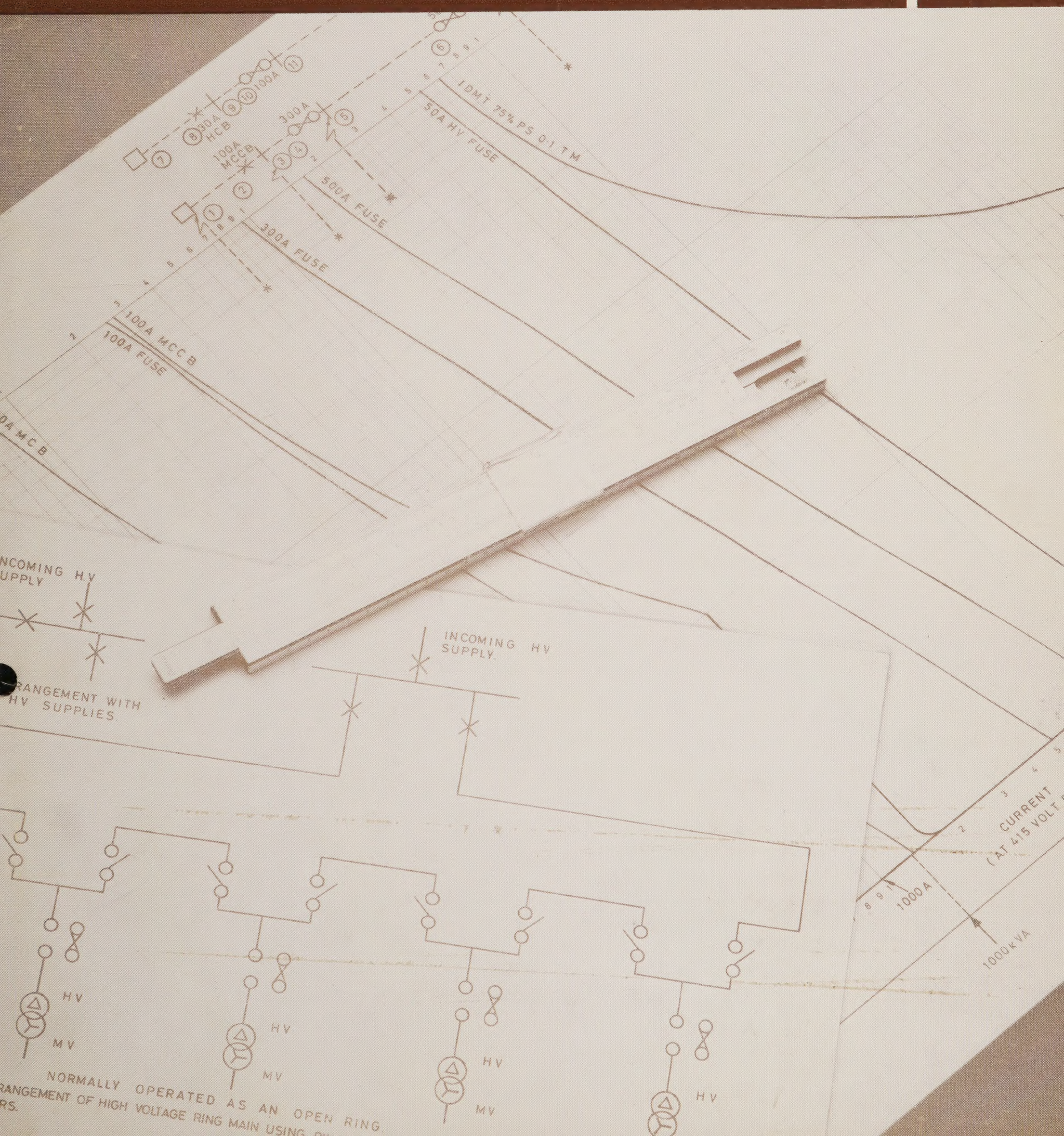

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Health Technical Memorandum Number 7

Electrical Services
Supply and Distribution

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I. Scope

1. This technical memorandum is intended to assist those engaged in the design of hospital electrical installations. It is applicable primarily to new hospitals and major developments but the principles will also apply when large alterations and extensions to existing electrical installations are planned and to certain other health buildings.

2. Guidance is given on choice of supply and distribution voltages and equipment, utilisation circuits, together with examples of typical distribution systems, sub-stations and switchrooms.

3. Lightning protection is dealt with in Appendix 4.

IIA. Abbreviations

4.

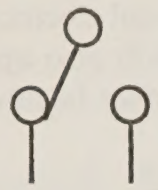
BS	British Standards issued by the British Standards Institution.
ERA	Electrical Research Association.
ep rubber	ethylene propylene rubber, complying with BS6899.
hrc	high rupturing capacity.
ESI Std	Electricity Supply Industry Standards.
HV	high voltage (see definitions)
idmt	inverse definite minimum time.
IEE Regulations	The Regulations for the Electrical Equipment of Buildings issued by the Institution of Electrical Engineers.
kA	kilo-ampere
kV	kilo-volt
kVA	kilo-volt-ampere
kVAr	kilo-volt-ampere, reactive
kW	kilo-watt
mcb	miniature circuit breaker complying with BS3871 Part 1.
mccb	moulded case circuit breaker complying with BS3871 Part 2.
mims	mineral insulated, metal sheathed.
mpfe	maximum prospective fault energy, under symmetrical fault conditions i.e. a short circuit between all three phases.
MVA	mega-volt-ampere.
MV	medium voltage (see definitions)
NJAC	National Joint Advisory Council of the Electricity Supply Industry.
pf	power factor.
pvc	polyvinyl chloride compound.

IIB. Definitions

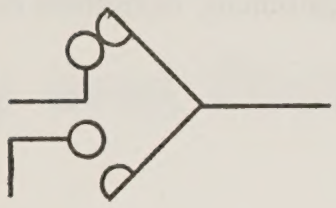
5.

Discrimination	Discrimination is the property of a protective system by which it is designed to isolate the faulty unit only, thus maintaining, as far as possible, the continuity of supply to sound equipment.
Load Factor	The ratio of a number of units supplied during a given period to the number of units that would have been supplied had the maximum demand been maintained throughout that period: usually expressed as a percentage.
Space Factor	The ratio (expressed as a percentage) of the total cross-sectional area of cables including insulation, bunched together, to the internal cross-sectional area of the conduit, trunking, etc. in which the cables are installed.
Medium Voltage	In this document means a voltage in a system normally above 250 volts but not exceeding 650 volts where electrical energy is used or supplied in accordance with the Fourteenth Edition of the IEE Regulations up to the 1970 amendments **(The April 1976 amendments of the IEE Regulations redefine medium voltage as low voltage band II).**
High Voltage	In this document means a voltage in a system normally above 650 volts where electrical energy is used or supplied.

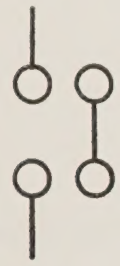
III. Symbols used in diagrams



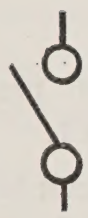
MANUALLY OPERATED
CHANGE-OVER SWITCH.



CHANGE-OVER CONTACTOR.

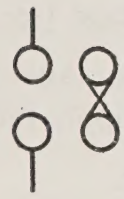


ISOLATOR USED AS BUS
SECTION SWITCH.



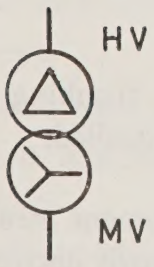
ISOLATOR.

SWITCH AND FUSE.



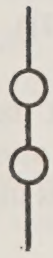
FUSE SWITCH (ON HIGH VOLTAGE
FUSE MAY BE STATIONARY AND
ISOLATED ON BOTH SIDES BY
INTERLOCKED OPERATING
MECHANISM).

CIRCUIT BREAKER.



TRANSFORMER SHOWING PRIMARY
AND SECONDARY WINDING
ARRANGMENT.

AC GENERATOR.



REMOVABLE LINK.

IV. Compliance with regulations

6. Installations should comply with the following regulations where appropriate:

a. Electricity Supply Regulations, 1937 (HMSO).

b. Electricity (Factories Act) Special Regulations, 1908 and 1944 (HMSO).

c. Current edition of the Regulations for the Electrical Equipment of Buildings (Institution of Electrical Engineers).

d. Overhead Line Regulations for Securing the Safety of the Public SI 1970 No. 1355 (HMSO).

V. Design procedures

7. The successful planning of an installation will depend on close liaison with all other disciplines involved with the project, to obtain as much information as possible about the use of each part of the premises and the equipment to be provided.

8. The design must proceed in step with architectural and mechanical designs. Where the planning of the project will be arranged in separate phases, each phase will be regarded as a separate scheme, but the outline planning of the whole will be completed before the detailed planning of the first phase commences.

9. Initially it will be necessary to establish in broad terms the probable total cost of the installation. This will involve estimating the maximum demand and having preliminary consultation with the supply authority to obtain information on availability and routing of supply mains, the possibility of an alternative supply, fault levels and probable tripping times at main intake sub-stations, details of their capital charge and tariffs which are applicable.

10. Under the provisions of the Electric Lighting (Clauses) Act 1899, consumers can be required, if the supply authority so decides, to meet the cost of supply lines which are required on their own property and for any supply lines in excess of 20 m. from an existing feeder. The supply authority may wish to provide their sub-station on the hospital site and this factor will be taken into account when negotiating the capital charge for providing the hospital supply.

11. The type of supply and method of distribution will have to be decided at sketch plan stages, the choice being influenced by layout, size and use of buildings and the location of the building relative to the supply authority's distribution system. It will be necessary to agree space requirements for accommodating electrical distribution equipment and their locations, with the architect. This will include arrangements for sub-stations, switch-rooms, horizontal and vertical ducts, etc. Wherever possible cables should be run direct in the ground, and cable conduit provided at road crossings or under concreted areas. (Some typical details are included in Appendices 1 to 3).

12. When the schedules of accommodation and information concerning major items of equipment are available the detailed planning of the installation including the specification and working drawings can be completed. At this stage, precise details of all builders work, openings, etc. should be given to the architect.

13. The electrical services (supply and distribution) specification would include:

Substations to accommodate transformers and switchgear, earthing arrangements, access for hospital and electricity boards staff.

Other typical items which are included in a general specification are:

Internal lighting

General lighting in all departments and communication spaces, special lighting for operating suites, wards, lecture rooms, assembly rooms, etc.

External lighting

Access roads, pathways, car parks, etc.

Electrical services for mechanical plant

Boiler house, heating and ventilation, hot water services, cold water pumping, sewer sump pumps, central medical gas installations, etc.

Electrical services for fixed equipment in other departments

Laundry, kitchen, diagnostic X-ray, pathology, etc.

General service socket outlets.

Emergency services

Lighting and power supplies, see Hospital Technical Memorandum No. 11—Emergency Electrical Services.

Fire alarms, see Hospital Technical Memorandum No. 16—Fire Precautions.

General alarm systems.

Telephone systems.

Nurse call and staff location systems.

Radio and television facilities for patients and staff.

Clock system including time clocks for staff.

Lifts, escalators, conveyors and paternosters.

Lightning protection.

VI. Tariffs and load factor

14. The type and choice of tariff available to hospitals may vary considerably with different supply authorities, and should be discussed at an early stage with the commercial engineer of the particular board. Normally two basic types of tariff are available, block or maximum demand. There is a maximum kVA limit for block tariffs and a minimum kVA limit for maximum demand tariffs but these values vary with different supply authorities. A maximum demand tariff will be applicable in most hospitals. Possible variations on both of the basic types of tariff include a reduced rate for night consumption and a reduced rate for weekend consumption.

15. As far as is practicable, the installation should be designed to spread the load over 24 hours, to obtain the optimum load factor and to take full advantage of any night and weekend rebates which are applicable. The important effect that the load factor has on the average cost per unit with a typical maximum demand tariff is shown in figure 1.

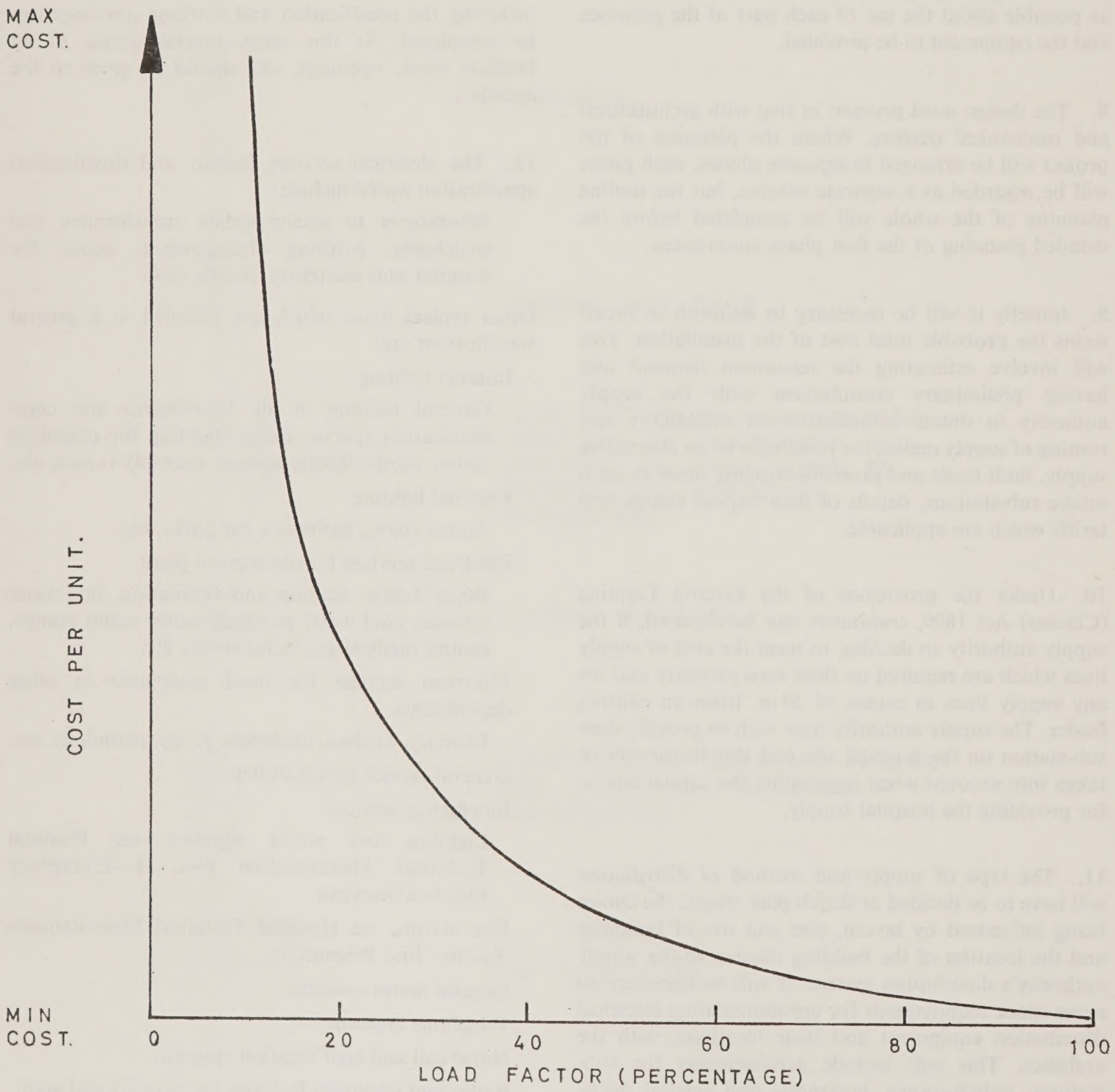


Figure 1 Graph showing relationship between load factor and cost per unit of electricity

VII. Design of installation for growth and change

16. Subsequent additions to an installation, unless planned and allowed for during the original construction can be costly, particularly when structural changes are involved. The aim should be to make adequate provision for known requirements including spare capacity in transformers, cables and bus-bars and where practicable include suitable provision to enable the installation to be extended. It is important to note that an increase in cable size initially is relatively inexpensive compared to the cost of installing an additional cable later. The installation should be designed to be as flexible as possible within the cost limits, to allow for possible future additions and alterations.

VIII. Estimated maximum demand

17. The estimated maximum demand will determine the capacity of the intake, size and location of main distribution equipment together with the method of distribution and will influence negotiations on the tariff with the electricity supply authority.

18. To obtain the installation maximum demand, schedules are required together with details of equipment. Details for subsequent phases may not be available and it will be necessary to estimate the ultimate maximum demand on the information available in relation to the complete project.

19. A sample of electricity bills from 240 hospitals carried out in 1975 provided an insight to typical maximum demands. In all these hospitals the heating was mainly non-electric. Table 1 is a summary of the maximum demands pertaining to various hospital classifications (column 1), some sub-divided by size which is expressed as the volume of buildings heatable by mainly non-electric means (column 2). The hospitals are classified in accordance with the scheme detailed in "Notes on Hospital Form SH3 for 1976". The maximum demands quoted in column 4 are derived statistically from electricity bills for the number of hospitals shown in column 3. Designers of hospital supplies and distribution can use the figures in column 4 assured in the knowledge that for a classified hospital they should satisfy 90% of hospitals in that classification.

TABLE 1

Maximum demand survey

1		2	3	4
Hospital classification		Size ($m^3 \times 30$)	No. of hospitals sampled	Statistical derivation of the maximum demand which would not be exceeded in 90% of hospitals sampled ($W/30m^3$)
Type No.	Description			
1, 2, 3 and 17	Short-stay	<500	21	313
		500—2000	27	218
		>2000	27	204
1, 2 and 3	Short-stay (new)	<4000	15	224
		>4000	11	204
4 and 5	Long-stay	—	26	178
11	Maternity	—	11	367
12 and 13	Psychiatric	<1000	15	242
12	Mental illness	>1000	20	140
13	Mental handicap	>1000	15	172
13	Mental handicap (new)	—	8	166
14	Orthopaedic	—	5	180
19(i)	Chronic and geriatric	—	25	294
—	Provincial teaching	—	14	175

20. Among the factors which will result in greater maximum demands are buildings having greater depth which require higher standards of lighting, and mechanical ventilation much of which will be required to operate continuously.

IX. Supply voltage

21. The voltage at which the supply authority will deliver the supply will be determined by the supply facilities which can be made available, the prospective load and the extent of the hospital distribution system.

22. The three options are:

a. A medium voltage supply [normally 240V/415V, 1/3 phase 4 wire] from the supply authorities MV network.

b. A medium voltage supply from a transformer sub-station located on hospital property, which may be for the sole use of the hospital, or may also supply other consumers. This type of supply is suitable for medium sized hospitals e.g. 100–700 kVA demand. The high voltage transformer and switchgear may remain the property of the supply authority.

c. A high voltage supply (usually 11 kV 3 phase 3 wire) from the supply authority's high voltage network. The hospital will be responsible for providing and maintaining the high voltage transformers, associated switchgear and cabling on the consumer side of the supply terminals (i.e. after the metering equipment).

23. A high voltage supply may possibly be more reliable and it may be easier for the supply authority to give the hospital preferential treatment in the event of load shedding becoming necessary. Consultation with the supply authority will however be necessary at an early stage, to ensure that the required supply facilities can in fact be made available.

24. Where the maximum demand of the hospital justifies it, the supply authority may provide a duplicated high voltage feeder arrangement. In general, because of the integrated nature of supply networks the increase in reliability which can be expected from a second feeder will be marginal, but the additional cost may be justified for a larger hospital.

X. Diversity factors

25. Diversity can be allowed when calculating the size of main and sub-main circuit conductors and switchgear. The amount of diversity allowed calls for special knowledge and experience and must be applied to each particular installation individually. The whole hospital complex must be considered taking into account future extensions as far as possible. The diversity factors applicable should be decided by the engineer responsible for the design.

26. As a general guide the following are typical examples of diversity factors.

Lighting	75%.
Socket outlets	2·5% of the maximum rating of the circuit.
Fixed equipment	100% of largest load plus 75% of next largest load plus 40% of the remainder.

XI. Distribution system

27. The distribution system should be designed to provide as much flexibility as possible within the cost limit allowance. Provision should be made for any known future extensions.

28. Adequate spare capacity should be allowed on bus-bars at main and sub-main distribution centres and on main and sub-main feeders. Space should also be allowed for additional switch and distribution equipment.

29. The choice of the supply voltage and type of distribution will be largely influenced by the size, shape and situation of the building(s).

30. At an early stage in the design the distribution system should be assessed for operational requirements, tripping times, fault levels and emergency supply provisions (see Hospital Technical Memorandum No. 11—Emergency Electrical Services) to provide a viable economical solution.

31. The increasing dependance of medical and nursing procedures on electrical apparatus calls for special attention to the electrical distribution system. It is important to note from Hospital Technical Memorandum No. 11—Emergency Electric Services that besides providing a supply for emergency circuits on main supply failure standby generators should be arranged to provide a supply to each important load

centre when a failure is sensed at the normal supply intake, e.g. a failure of the normal intake cable to the sub main distribution centre.

32. The system should be simple yet reliable and easy to maintain safely particularly where an 11 kV distribution system is envisaged (See Hospital Technical Memorandum No. 21—Safety Code for High Voltage Installations).

33. The total cost of alternative distribution systems should be calculated for each particular project using the present worth technique of cost calculation. The cost comparison should include:—

a. Annual capital cost of switchgear, cables, including building space occupied.

b. Where appropriate, the annual capital cost of transformer and the transformer chamber based on a useful transformer life of 30 years.

c. Annual cost of cable losses and transformer losses, where appropriate, allowing a load factor of 60% and based on the assumption that the most economic size of cable is used also taking voltage drop into consideration (see paras. 36 and 37).

d. Annual maintenance cost of switchgear, cables and transformers where appropriate.

34. The distribution circuits between the main intake and load centres may be radial or ring distribution feeders.

35. There are a number of methods for designing the distributor system. Typical examples are as follows:

a. A ring main system for normal supplies together with a ring main system for emergency supplies.

b. A ring main system for normal supplies together with a radial feeder system for emergency supplies.

c. A radial system for normal supplies together with a radial system for emergency supplies.

d. A radial system for normal supplies together with a ring main system for emergency supplies.

36. To comply with the IEE Regulations the medium voltage installation conductors should be selected to ensure that the potential drop does not exceed 2·5% from the consumers terminals to the remote outlets when the conductors are carrying the full load current, disregarding motor starting conditions. For a medium voltage intake from the supply authority the consumer terminals are at the main switchboard. (See Figure 2(a).)

37. Where the intake is at high voltage from the supply authority, the hospital will generally be responsible for the complete installation including high voltage switchgear, cables and transformer(s). For the purpose of the IEE Regulations, the "consumers terminals" will be where energy is supplied to the installation at medium voltage, i.e. 415V ± 6%. This point will be at the main medium voltage distribution centre or, if suitable tap changing facilities are provided on the transformer(s), at the sub-main distribution centre(s). Where extensive medium voltage feeders are run to sub-main distribution centre(s) in the hospital complex, the feeder conductor size can be determined by the load, rather than the voltage drop, if tap changing facilities are provided. (See Figure 2(b)).

38. The probable voltage drop should be calculated before deciding whether to use high voltage or medium voltage for the main distribution. It may be found that medium voltage systems are neither economic nor practicable due to the large voltage drop and size of cable required to comply with the IEE Regulations and the volume of the building space such cables would occupy.

39. The choice of the voltage for the main distribution will generally depend upon the economic considerations (see paragraph 33) arising from distance between the various load centres of the hospital and the main intake position.

40. In marginal instances, preference should be given to high voltage for the main distribution system for the reasons given in paragraph 23. Where high voltage distribution is economically justified, 11 kV is the preferred voltage (BS77).

XII. High voltage distribution

General

41. Where high voltage distribution is employed for the main distribution system, the aim should be to cover as much of the distribution as is practicable with high voltage cables and keep the medium voltage cable as short as possible. The system should be as simple as possible, consistent with safety and the need to achieve, under fault conditions, the degree of discrimination which will limit disconnections to an acceptable level.

42. High voltage switchgear and protection equipment is expensive and each unit is a possible source of failure, therefore only essential protective and switching units should be provided.

43. Where HV Switchgear is provided by the supply authority, it may be unnecessary for the equipment to be duplicated as part of the hospital installation, since it is usually possible to have an arrangement with the supply authority whereby their switchgear may be tripped in an emergency by hospital personnel. In some instances HV switchgear is provided on a shared basis.

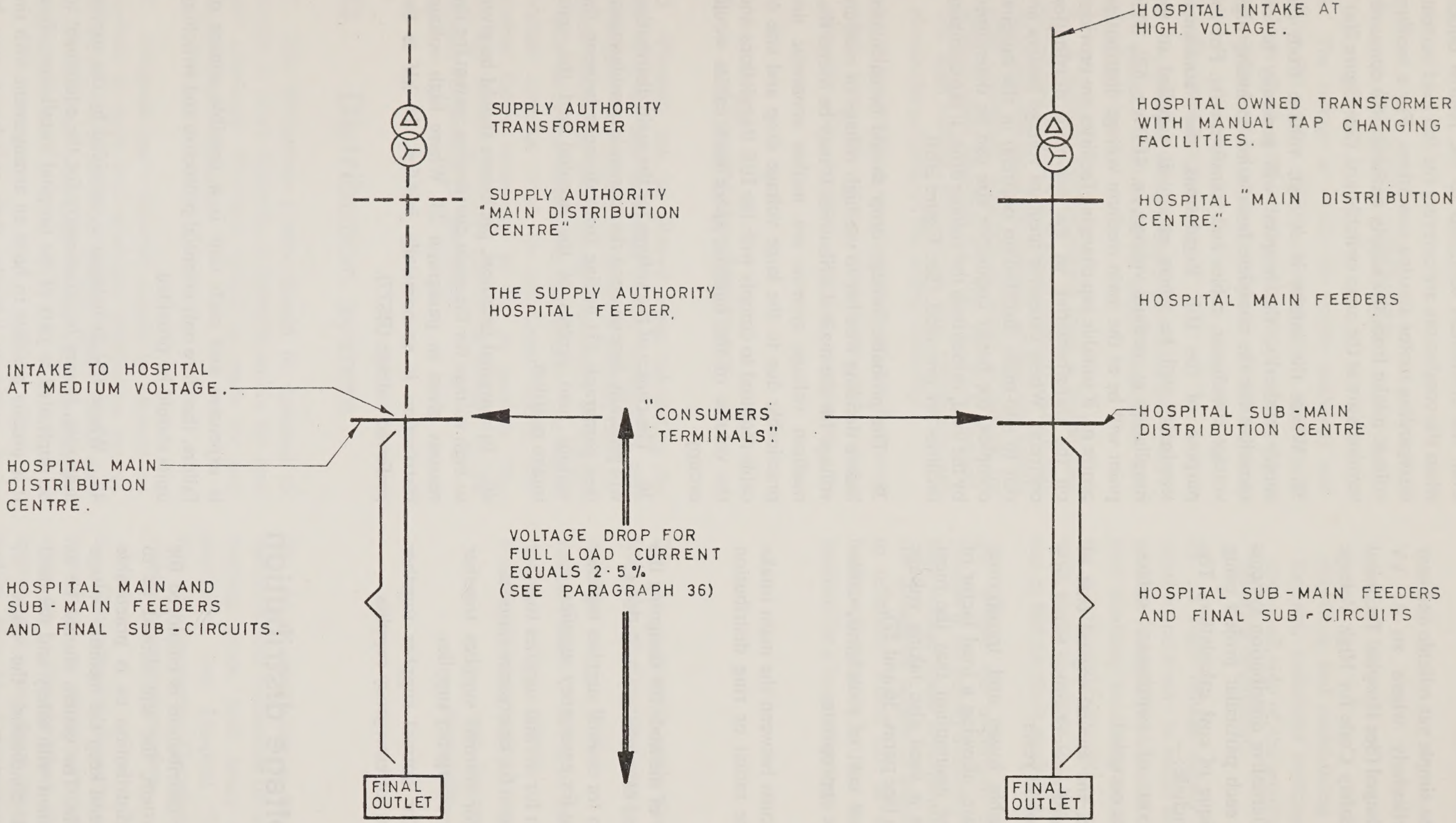

SUPPLY AUTHORITY TRANSFORMER
SUPPLY AUTHORITY "MAIN DISTRIBUTION CENTRE"
THE SUPPLY AUTHORITY HOSPITAL FEEDER.
INTAKE TO HOSPITAL AT MEDIUM VOLTAGE.
HOSPITAL MAIN DISTRIBUTION CENTRE.
HOSPITAL MAIN AND SUB-MAIN FEEDERS AND FINAL SUB-CIRCUITS.
"CONSUMERS' TERMINALS"
VOLTAGE DROP FOR FULL LOAD CURRENT EQUALS 2·5% (SEE PARAGRAPH 36)
FINAL OUTLET
(a) INTAKE TO HOSPITAL AT MEDIUM VOLTAGE (SEE PARAGRAPH 36)
HOSPITAL INTAKE AT HIGH VOLTAGE.
HOSPITAL OWNED TRANSFORMER WITH MANUAL TAP CHANGING FACILITIES.
HOSPITAL "MAIN DISTRIBUTION CENTRE."
HOSPITAL MAIN FEEDERS
HOSPITAL SUB-MAIN DISTRIBUTION CENTRE
HOSPITAL SUB-MAIN FEEDERS AND FINAL SUB-CIRCUITS
FINAL OUTLET
(b) INTAKE TO HOSPITAL AT HIGH VOLTAGE WHERE TRANSFORMERS ARE HOSPITAL OWNED AND HAVE MANUAL TAP CHANGING FACILITIES (SEE PARAGRAPH. 37)

Figure 2 Voltage drop for medium or high voltage intakes

44. All electrical equipment should be capable of dealing safely with the maximum prospective fault energy (mpfe) to which it is subjected. The fault level at the hospital intake will depend upon the arrangement of the supply authority's distribution network, and the value should be obtained from the authority. HV distribution which forms part of the hospital installation should be so arranged to limit the fault level as far as is convenient and practicable, e.g. by limiting the size of transformers and providing interlocks on bus-bar couplers to prevent paralleling of supply feeders and transformers. Advice on the calculations of short circuit currents is given in BS116 and BS4752.

45. High voltage system protection should limit the extent of supply interruptions under fault conditions, and should be considered in conjunction with the provision of emergency supplies (see Hospital Technical Memorandum No. 11—Emergency Electrical Services) which are provided to maintain essential services during interruptions of the normal supply.

Ring circuits

46. Oil switches and high voltage fused switch protection for transformers when used in conjunction with a ring distribution system as shown in Figure 3 would generally provide a satisfactory arrangement. This system would normally operate as an open ring so that a fault on one leg of the ring would cause a loss of supply to that leg only. The probability of a fault on the HV distribution system is slight making this a generally acceptable arrangement particularly where automatic standby generator(s) are available for supplying any essential circuit which is de-energised due to a fault in a main or sub-main cable from the normal supply.

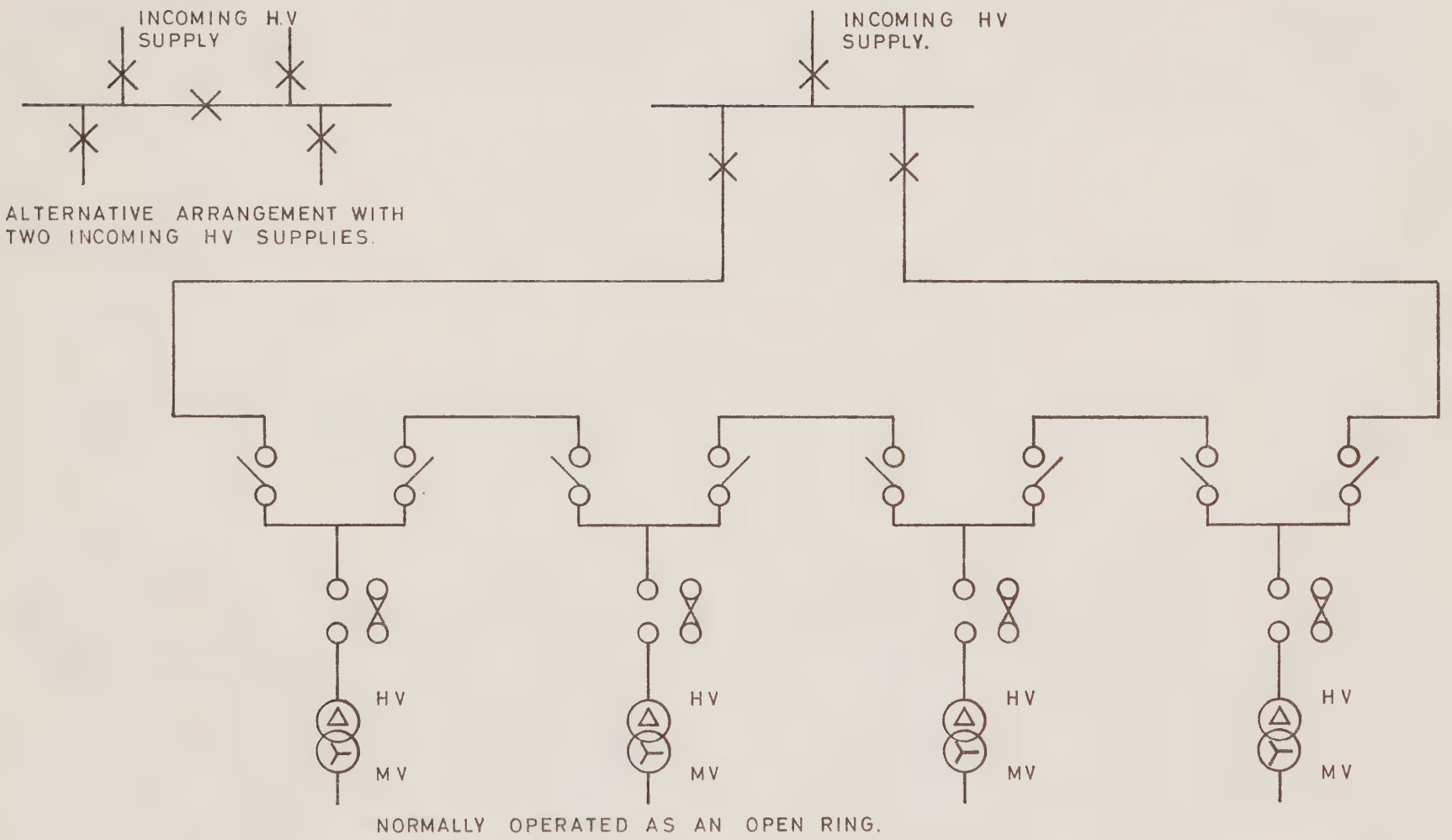


Figure 3 Typical arrangement of high voltage ring main using ring main units and fused switch protection for transformers

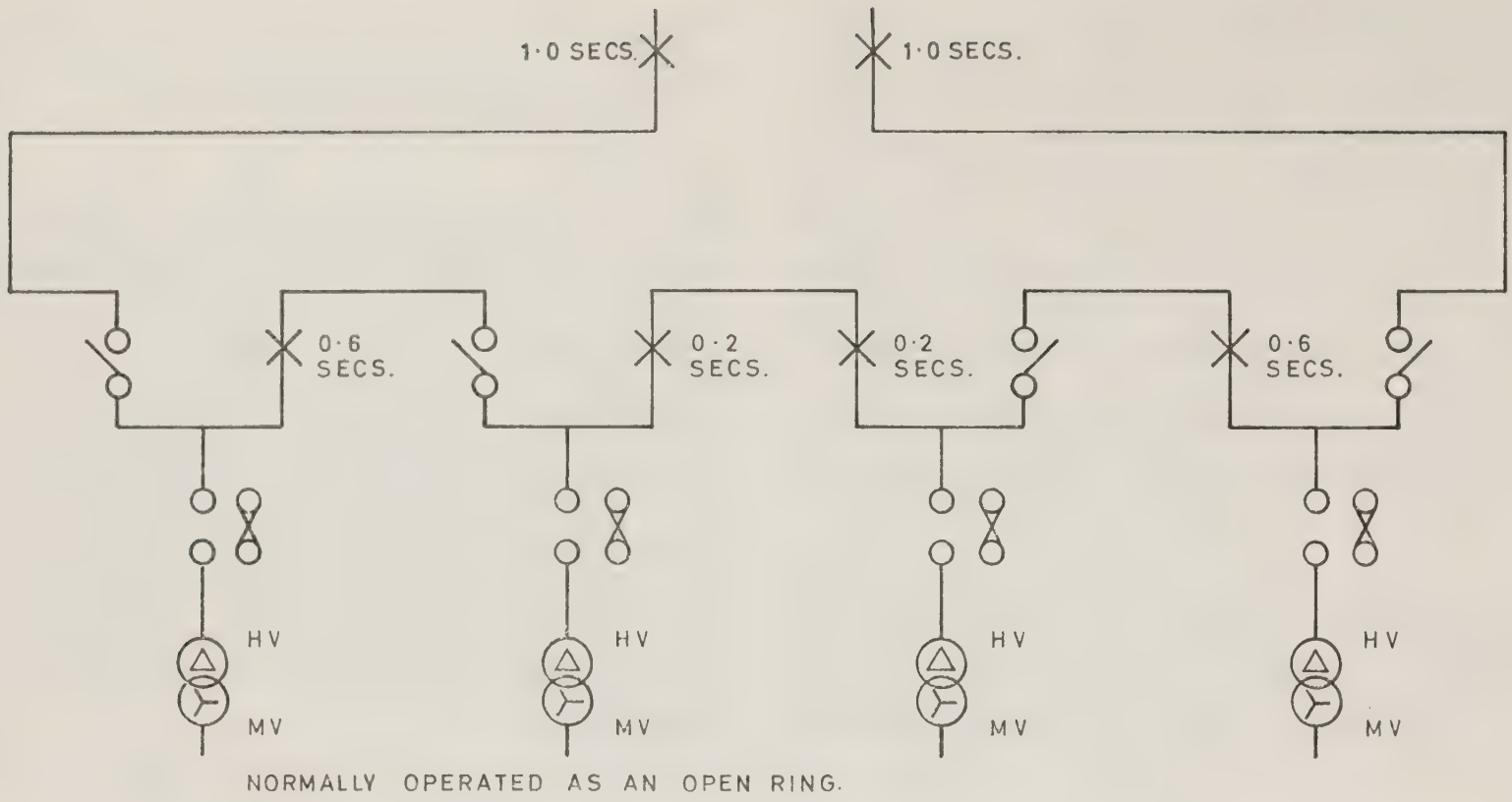


Figure 4 Arrangement of high voltage ring main units with ring isolator, circuit breaker and fused switch protection for transformers

47. If a system requiring more selective tripping for an HV distribution fault can be justified, the arrangement shown in Figure 4 provides this. The system would operate as an open ring but a fault on one leg would not necessarily cause a loss of supply to the whole of the leg; the portion of the leg which is de-energised would depend on the location of the fault.

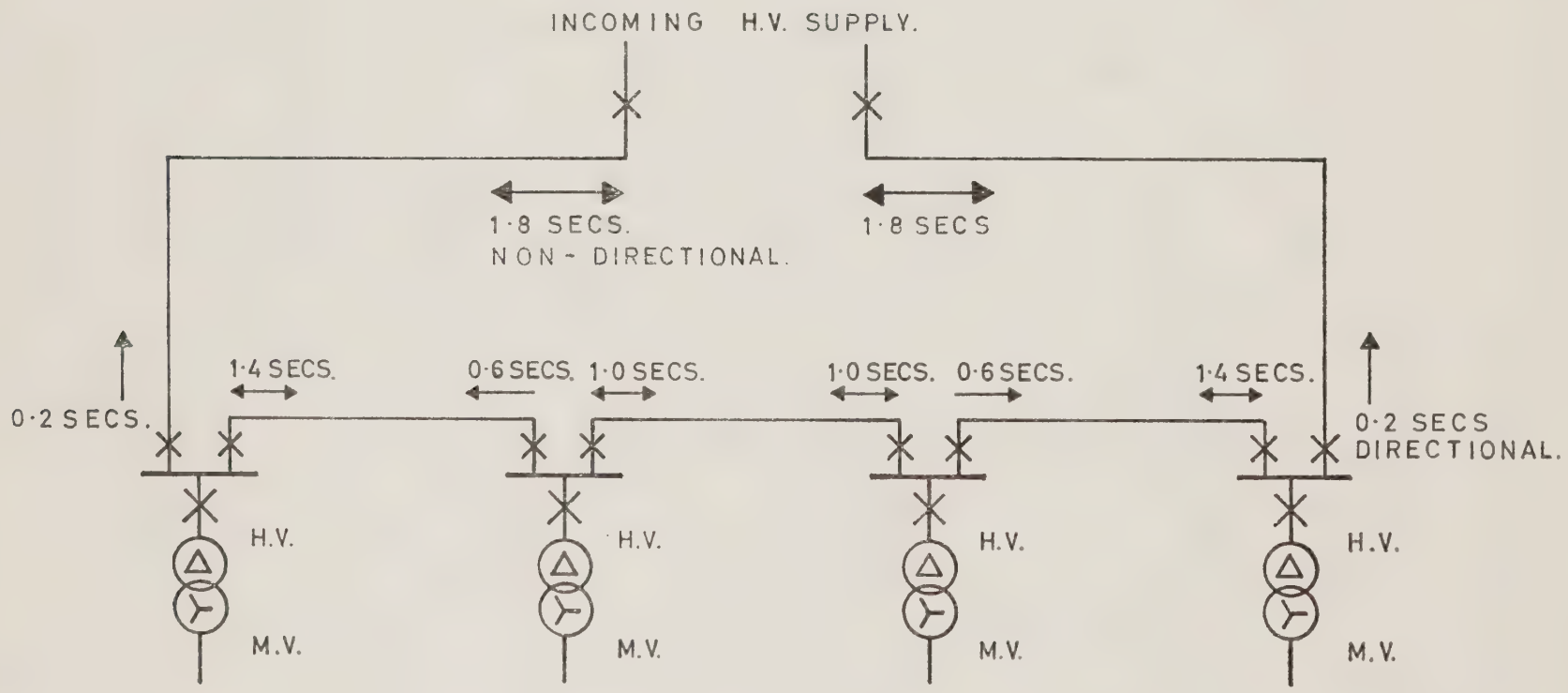


Figure 5 High voltage ring main with directional protection using graded time-lag relays

48. It is unlikely that an even higher degree of tripping selectivity will be required but where this can be justified either of the arrangements shown in Figures 5 or 6 will limit the isolation on fault to the faulty section only. Whereas the biased differential protection system (Figure 6) provides instantaneous tripping for a HV ring main fault, the large tripping times of breakers nearest the source of supply in the directional graded protection system (Figure 5) might entail using some larger ring main cables. When assessing the extra cost of the larger sized cabling for the directional graded protection system, the cost of the pilot cabling required for a differential protection system should be set against this.

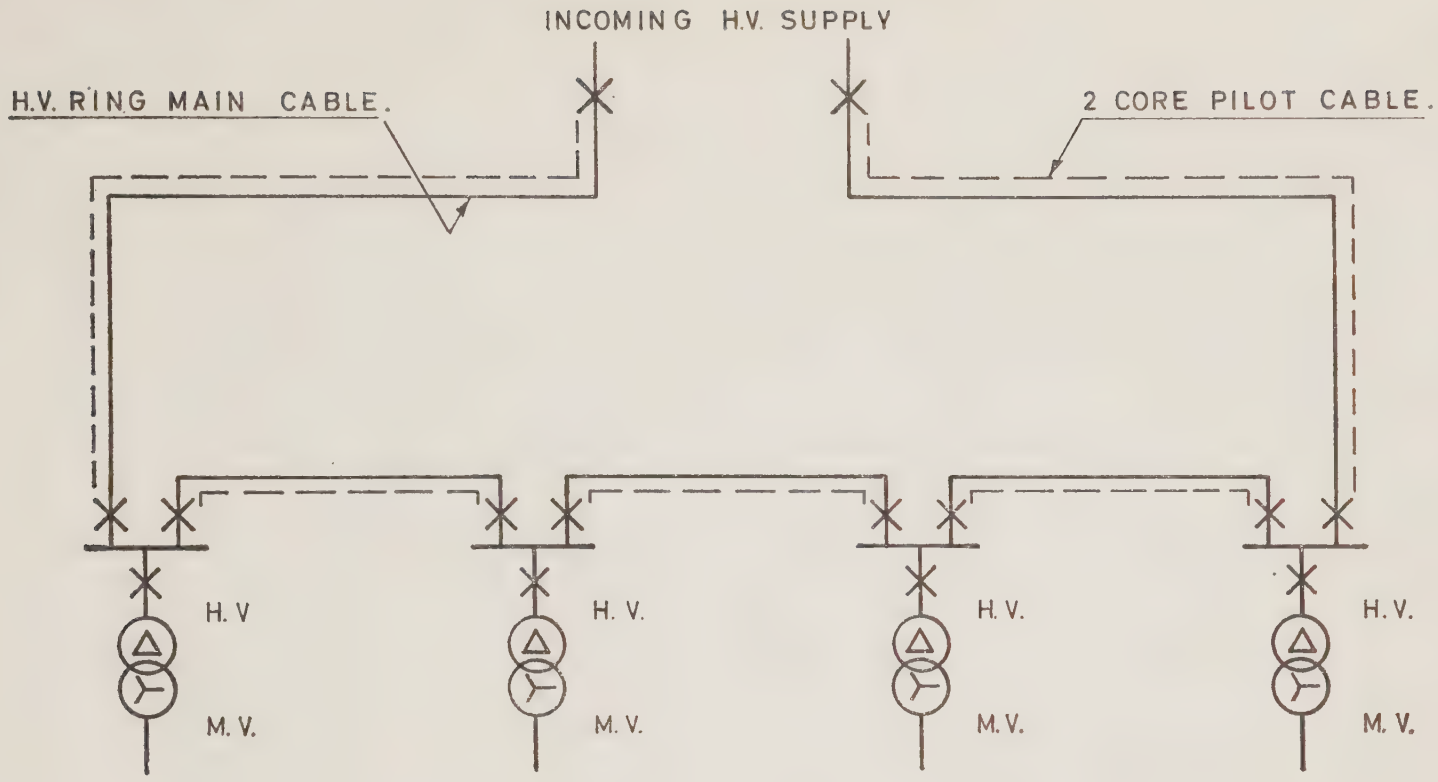


Figure 6 High voltage ring main using differential current protection with back-up protection at main sub-station, and overcurrent, and earth fault protection for transformers

Radial distribution

49. With this type of distribution, isolation on fault is limited to the faulty section only. To provide some of the flexibility for maintenance inherent in ring distribution systems it is normal to provide the medium voltage interconnectors shown in Figure 7 which is typical of a radial distribution system. The emergency supplies are not shown, these being in accordance with Hospital Technical Memorandum No. 11—Emergency Electrical Services. An alternative emergency supply distribution system, which is not specifically referred to in Hospital Technical Memorandum No. 11—Emergency Electrical Services, is shown in Figure 8, the normal supplies being HV radial feeders and the emergency supply system being a MV ring main system. With this single generator system the MV ring main would normally operate closed; it would normally operate open if two generators were used as is more probable.

50. Where the ratio of essential to non-essential load is high, and long lengths of cable are required between generator(s) and load centres, (e.g. in high rise, elongated low rise or dispersed hospitals), it may be uneconomic to generate at medium voltage. In such instances high voltage generation should be considered; Figure 9 shows a typical radial system with high voltage generators. It should be noted that in this system the essential cables are permanently energised making full use of the installed conductors whilst providing continuous monitoring. The disadvantage with this system is that it does not provide a supply for the essential or non-essential sections of the load centre, on failure of the appropriate feeder.

Circuit protection

51. Appendix 5 Figure 20 includes HV main distribution protection which is typical of that used in hospitals for adequate discrimination. It will be clear from Figures 3, 4, 7, 8 and 9 that the principles are applicable to ring or radial HV main distribution systems.

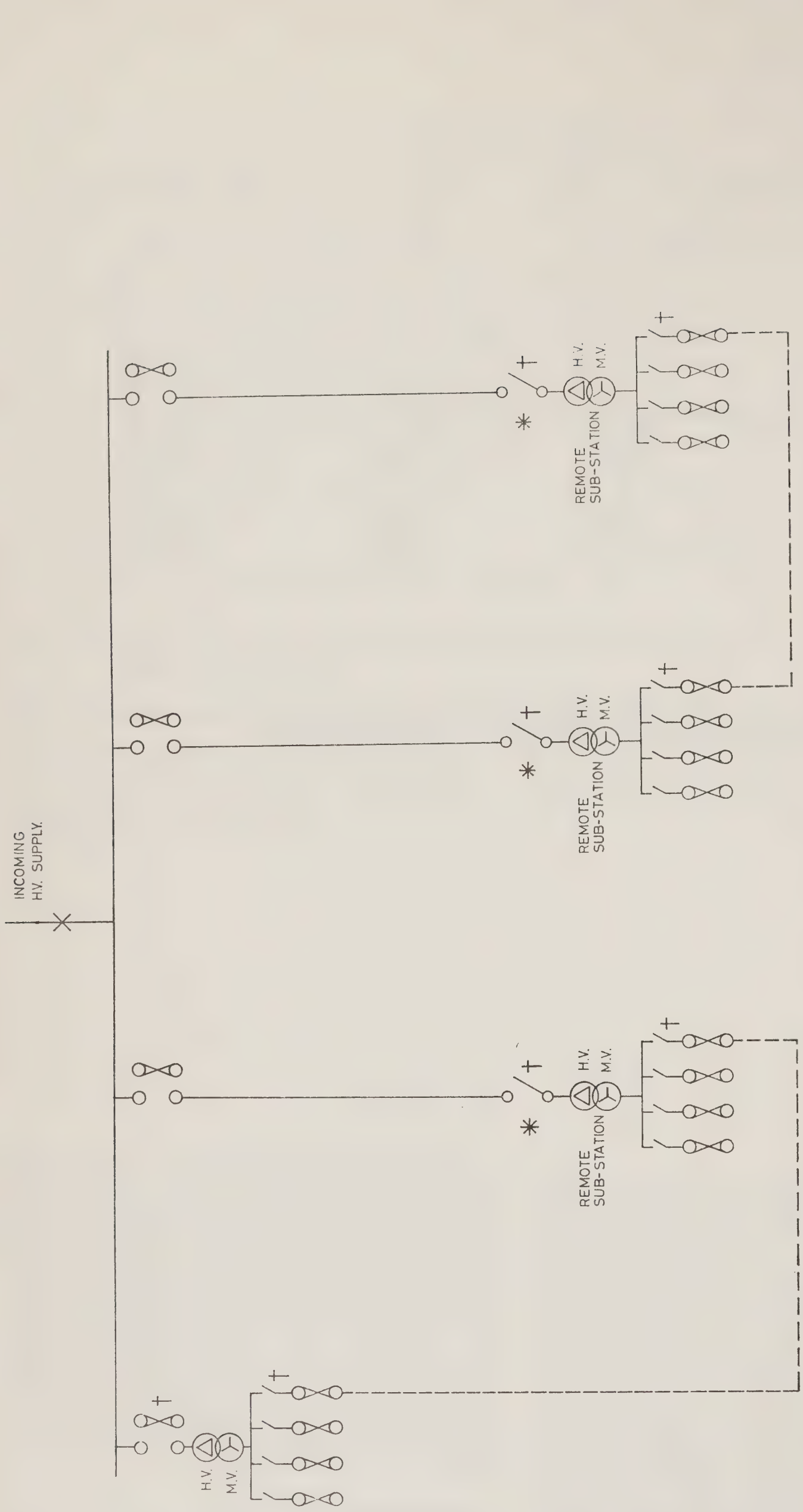

INCOMING
H.V. SUPPLY.
REMOTE
SUB-STATION
H.V.
M.V.
MEDIUM VOLTAGE
INTERCONNECTOR
* H.V. ISOLATOR REQUIRED AT REMOTE SUB-STATIONS.
† SWITCHGEAR TO BE KEY INTERLOCKED TO PREVENT PARALLELING OF TWO SUPPLIES, BUT TO PERMIT INTERCONNECTION OF BUSBARS WHEN SUPPLIED FROM SINGLE SOURCE.

Figure 7 High voltage radial distribution with medium voltage interconnectors

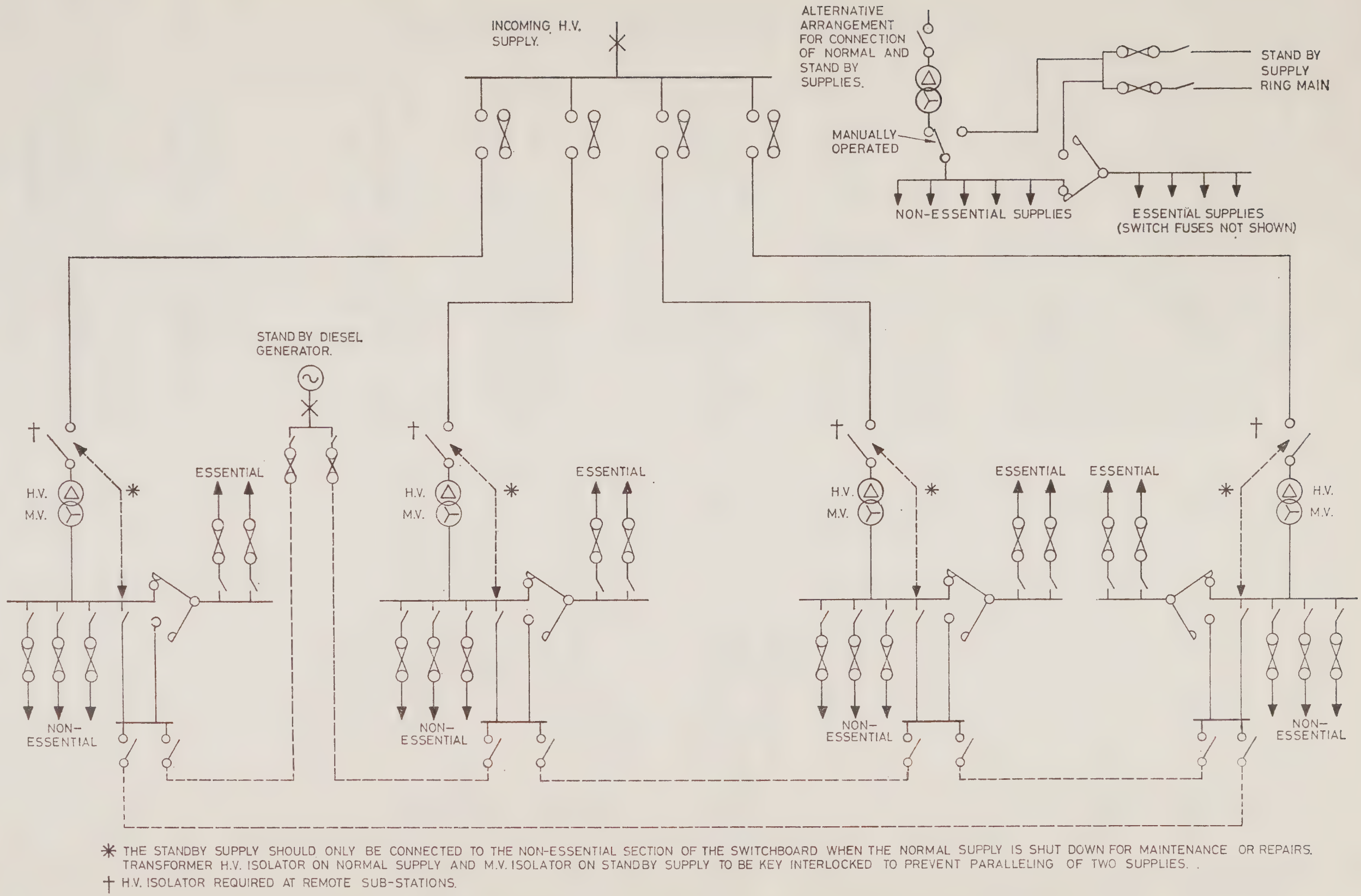

INCOMING H.V. SUPPLY.
ALTERNATIVE ARRANGEMENT FOR CONNECTION OF NORMAL AND STAND BY SUPPLIES.
MANUALLY OPERATED
STAND BY SUPPLY RING MAIN
NON-ESSENTIAL SUPPLIES
ESSENTIAL SUPPLIES (SWITCH FUSES NOT SHOWN)
STAND BY DIESEL GENERATOR.
H.V.
M.V.
ESSENTIAL
NON-ESSENTIAL
* THE STANDBY SUPPLY SHOULD ONLY BE CONNECTED TO THE NON-ESSENTIAL SECTION OF THE SWITCHBOARD WHEN THE NORMAL SUPPLY IS SHUT DOWN FOR MAINTENANCE OR REPAIRS. TRANSFORMER H.V. ISOLATOR ON NORMAL SUPPLY AND M.V. ISOLATOR ON STANDBY SUPPLY TO BE KEY INTERLOCKED TO PREVENT PARALLELING OF TWO SUPPLIES.
† H.V. ISOLATOR REQUIRED AT REMOTE SUB-STATIONS.

Figure 8 High voltage radial distribution with medium voltage standby ring interconnector

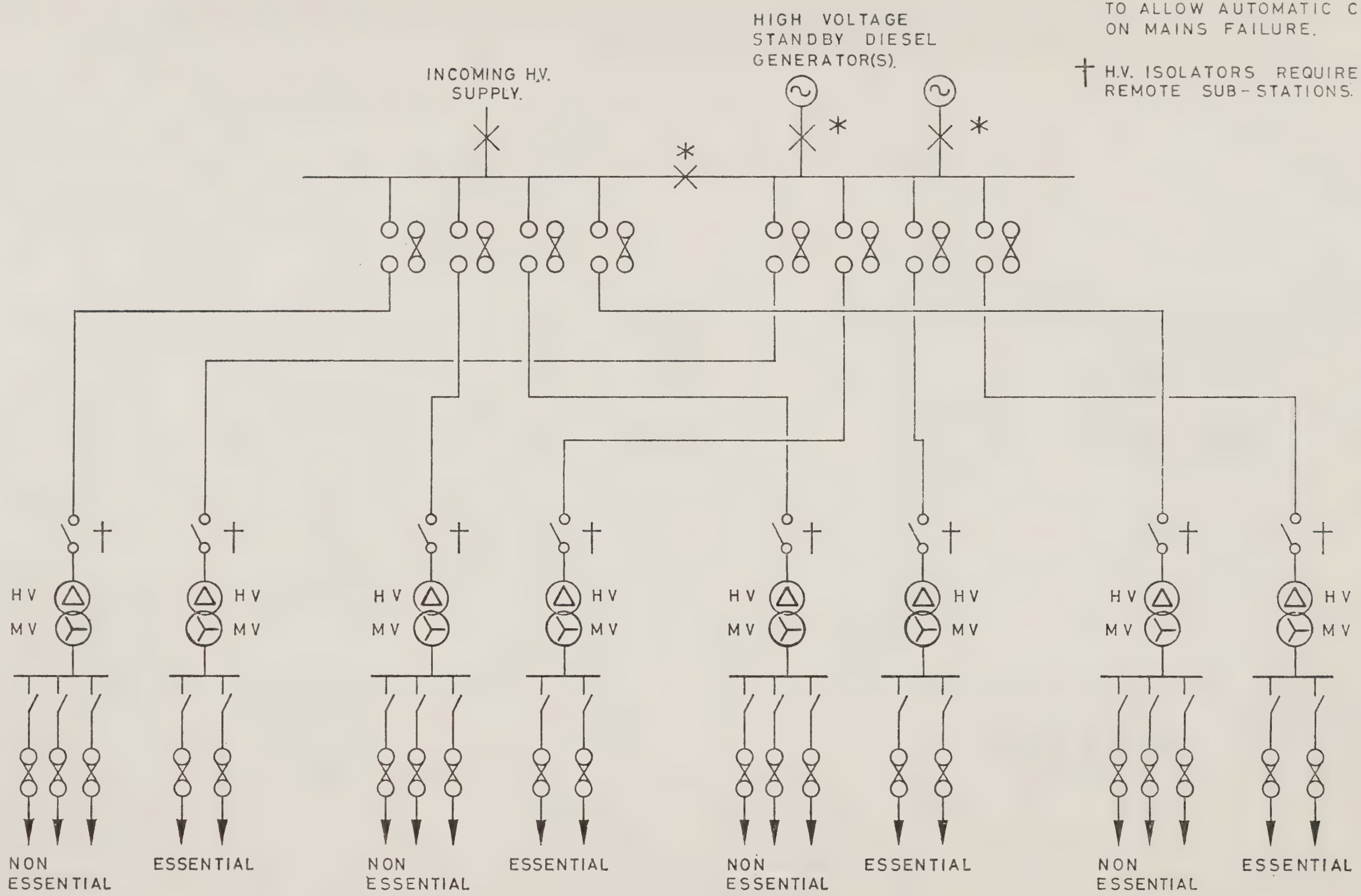


Figure 9 High voltage radial distribution with high voltage generators

XIII. High voltage switchgear

General

52. High voltage switchgear will normally be of the oil-break type with air insulated or compound filled bus-bar and current transformer chambers. With some compound filled units the current transformers are oil immersed. Air insulated units would normally be used indoors and compound filled types outdoors. It is important that the maximum breaking capacity of switchgear should exceed the mpfe of the supply system (which should be verified with the supply authority) and a certificate of type test should be obtained from the switchgear manufacturers. The standard MVA ratings for 11 kV switchgear are 250 MVA and 350 MVA. A typical current rating for a hospital system would be 400 amperes.

53. The Electricity Supply Industry has a standard specification for distribution switchgear (ESI 41–5) which covers indoor metalclad switchgear having fault energy ratings of up to 250 MVA at 6·6 kV and 350 MVA at 11 kV. Oil circuit breakers should be in accordance with BS116 and oil switches with BS2631.

High voltage circuit breakers

54. Simplest types utilise direct acting trip coils which operate from current transformers. This type of protection is suitable for circuits which do not require accurate time grade tripping discrimination. Where such discrimination is important the sensitive idmt relays used require a dc supply (normally 30V, see paragraph 56).

55. Earth faults on cables will normally be of sufficient magnitude to operate the over-current protection, but it is usually considered desirable to provide both earth fault and over-current protection on the main hospital intake breaker(s).

Trip coil supply

56. An earth-free direct current supply (normally 30V) is required to energise the trip coil circuits and an alkaline type battery is normally used for this purpose. In determining the battery voltage, allowance should be made for the voltage drop in the wiring to ensure that the coils operate at their rated voltage. Charging facilities should include an automatic low charging rate with manually controlled quick charging facilities.

57. The capacity of the battery will depend on the power consumption of the trip coils and the number of units to be supplied. Normally a battery within the range 10–25 ampere-hours would be suitable.

58. The battery should be housed in a fire-resisting (e.g. steel) enclosure. Wiring between battery and switchgear should have good fire resisting properties (e.g. mims cables) and should be segregated from the high voltage and main medium voltage feeders.

Current transformers

59. Current transformers for use with protective equipment should comply with BS3938.

Interlocks, safety shutters and labelling

60. Mechanical interlocks, safety shutter devices and labelling should be provided as specified in ESI Std 41–5.

High voltage oil switches

61. Oil switches are considerably cheaper than oil circuit breakers, but are not suitable where time graded discrimination protection is required unless used in conjunction with fuses. (see Figures 3 and 4).

High voltage fused switches

62. Fused switches are about two-thirds the cost of a comparable circuit breaker. They are normally equipped with hrc fuses complying with BS2692. They are suitable for protection where time discrimination is required. (see Appendix 5).

XIV. High voltage cables

63. All cable must be capable of satisfactorily withstanding the prospective fault current of the system for the maximum period of time needed for the fault to be cleared by the protection equipment. The thermal effect under fault conditions increases as the square of the time and this is a very important factor where time discriminating protection is employed.

64. The current ratings of high voltage cables are given in the Electrical Research Association document 69–30. Part 1 deals with paper insulated lead sheathed cables complying with BS6480 (part 1). Part 3 of the ERA document deals with pvc insulated cables up to 3·3 kV (which is not a preferred voltage in hospitals, see paragraph 40) complying with BS6346. Appropriate

rating factors are given for non-standard laying depth and temperature conditions.

65. Tables 2 and 3 give the recommended minimum cable sizes for various fault levels and maximum fault duration times; the cable sizes indicated having been derived from the formulae:

$A = \frac{I_{SC}\sqrt{t}}{119}$ for copper conductors and

$A = \frac{I_{SC}\sqrt{t}}{76}$ for aluminium conductors, where A = size of conductor in mm^2, I_{SC} = current in amperes, and t = time in seconds, based on the assumption of a cable's initial conductor temperature of 65°C and a maximum conductor temperature not exceeding 160°C. The permissible size of some of the larger copper conductor pvc bedded cables is determined by the need to avoid damage on earth faults where the earth fault current flows through sheath and armour. Higher sheath temperatures are acceptable with textile bedded armouring, the cable sizes in brackets in Table 2 take this factor into account.

TABLE 2

Recommended minimum cable sizes for various prospective fault MVA values and fault duration times for 11 kV. 3 core copper conductor, paper insulated, belted, lead sheathed, single wire armoured cables.

Copper conductor sizes in mm^2 for fault duration in seconds.

MVA	0·2	0·3	0·5	1·0	1·5	2	3	Seconds
150	35	50	50	70	95	95	120	Conductor size in mm^2
200	50	50	70	95	120	150	240* (185)	
250	70	70	95	120	150	240* (185)	300* (240)	

*Size determined by earth fault capacity of pvc bedded cables. Sizes in brackets apply for textile bedded cables.

TABLE 3

Recommended minimum cable sizes as above, but using aluminium conductors.
Aluminium conductor sizes in mm^2 for fault duration in seconds.

MVA	0·2	0·3	0·5	1·0	1·5	2	3	Seconds
150	50	70	95	120	150	150	185	Conductor size in mm^2
200	70	95	120	150	185	240	240	
250	95	95	150	185	240	300	300	

66. The choice of cable will be largely influenced by cost comparisons. The cost saving with aluminium types of cables is resulting in their being increasingly used and can be a very significant factor with larger schemes.

67. Belted paper insulated cables have an additional outer layer of paper insulation to increase resistance to bursting under fault conditions. Alternative types which are slightly more expensive have a metallic screen surrounding each core to reduce the tangential stress of the electrostatic field arising from the use of high voltage. Experience has shown that belted cables are satisfactory for potentials up to 11 kV and should therefore be suitable for most hospital applications.

68. Cables should be joint-free as far as is practicable. Where joints are necessary they should be made in accordance with the Code of Practice on the design of High Voltage Joints, Electricity Council, Engineering Recommendation C34.

69. For short runs in conduits or covered ducts (e.g. in sub-stations) armoured cables will not normally be required. For longer indoor runs involving bends, cables having single wire armouring should be used to reduce the possibility of damage to insulation and sheath during installation. Compounded fibrous types of serving are highly flammable and should not be used on internal feeders. This type of serving should be

removed from external feeds at and from the point of entry into buildings.

70. All cables should be of a non-draining type and satisfy the test specified in BS6480 in this respect.

71. For external runs, single wire armoured and served cables are usually preferred. Where cables are liable to be subjected to excessive stresses e.g. where land subsidence is likely, double wire armouring should be specified.

XV. High voltage transformers

Types of transformers

72. Four types are available, namely, oil immersed, askarel immersed, dry type or dry type resin cast.

73. Askarel immersed cost approximately 40% more than oil immersed, dry type cost approximately 80% more than oil immersed and resin cast cost approximately 140% more than oil immersed. Other comparisons of these transformers are given in Table 4.

TABLE 4

Comparison of transformers with copper windings (11kV). The figures are approximate.

Capacity kVA	Transformer type	No load loss (Watts)	Load loss (Watts at 75°C)	Total Mass (kg)	Impedance Volts (% at 75°C)	Mean sound level [dB(A)]*
315	Oil immersed	700	4800	1524	4·75	50
	Askarel immersed	700	4800	2092	4·75	—
	Dry type	1250	4935	1640	5·00	—
500	Oil immersed	1030	6860	2270	4·75	52
	Askarel immersed	1030	6860	3180	4·75	—
	Dry type	1600	5640	2200	5·00	—
	Dry type resin cast	1340	5700	2350	4·00	—
800	Oil immersed	1500	10000	3200	4·75	54
	Askarel immersed	1500	10000	4120	4·75	—
	Dry type	2300	7980	2420	5·00	—
	Dry type resin cast	1700	8300	3000	6·00	—
1000	Oil immersed	1770	11800	3850	4·75	55
	Askarel immersed	1770	11800	4990	4·75	—
	Dry type	2750	9540	3310	5·00	—
	Dry type resin cast	2250	8400	3900	6·00	—

*Average maximum surface noise quoted in ESI Std 35–1. With the transformer operating at its noisiest condition between no load and permissable overload, its mean near field level when measured on a hemisphere reference radius of 3 m centred on the geometric centre of the transformer, shall be determined from at least 5 readings made in accordance with BS4196, and should not exceed the dB(A) indicated.

74. In considering the economics of the four types it is necessary to take into account the related fire risks, as fire precaution measures can be a significant factor with oil immersed transformers in indoor sub-stations.

75. Oil immersed transformers have been extensively used and experience has shown them to be very reliable. The only real disadvantage is the high flammability of the insulating oil. In low fire risk areas and particularly for outdoor sub-stations oil immersed transformers would be an obvious choice. Oil immersed transformers should only be installed at ground floor level.

76. In high fire risk areas askarel immersed transformers provide an alternative in which the insulating liquid is inherently non-inflammable.

77. Dry and dry resin cast type transformers are the most expensive and the dry type is noisier. Their use would be largely influenced by their lower flammability compared with oil immersed transformers. They do not have the fire resisting properties of askarel immersed transformers, but are not as heavy.

Number of transformers

78. The number of transformers required will depend on the load and the extent of the distribution. It is advisable that a minimum of two transformers should be provided and that emergency switching facilities should be included to enable a supply to be maintained to each section of the installation in the event of a failure involving a transformer or high voltage feeder.

79. With a compact hospital, two or more large transformer units installed in a centrally sited sub-station will normally provide the most economical arrangement. On larger dispersed hospital sites, a larger number of transformers may provide the most economical distribution. The aim should be to cover as much distribution as is practicable with high voltage cables. Figures 3 to 9 show typical distribution circuits.

80. With the cyclic load pattern normally experienced in hospitals, and taking into consideration capital cost, depreciation, copper and iron losses, it may be economic to overload transformers. CP1010 gives guidance to the loading of oil immersed transformers.

Size of transformers

81. On a cost per unit kVA basis, the cost of transformers varies inversely as the capacity increases to 500 kVA and then tends to become more directly proportional. For hospital applications the most useful size of transformers are those having a capacity of 500 kVA. In large compactly planned hospitals it may be more economical to raise the maximum capacity to 1000 kVA. In general it is desirable to limit the capacity to restrict the fault level on the medium voltage installation and also reduce the extent of interruption of supply in the event of a failure involving one of the transformers.

Oil immersed transformers

82. The ESI Std 35–1 has the aim of standardisation and rationalization with a view to saving costs. Transformers complying with this standard will be suitable for hospital applications where the use of oil-immersed transformers is considered appropriate.

83. ESI Std 35–1 is based on BS171 type ONAN. The standard sizes appropriate to hospital uses are 315, 500, 800 and 1000 kVA, with off-circuit primary tap changing facilities to allow $\pm 2\frac{1}{2}\%$ and $\pm 5\%$ variation of the primary voltage on all sizes. The specified winding connection for 3 phase transformers is delta-star, with Vector—Group Symbol Dy 11. The percentage impedance is 4·75% at 75°C. The figures for oil immersed transformers quoted in Table 4 are specified in ESI Std. 35–1.

84. Oil conservators and gas and oil actuated relays (Buchholtz) are not considered necessary for the size of transformer generally used for hospitals.

85. The construction of transformer chambers suitable for oil immersed transformers and appropriate fire precautions is dealt with in Appendix 1.

Askarel immersed transformers

86. Where mineral oil in transformers constitutes an unacceptable fire risk, synthetic insulating liquids known as askarels may be used as an alternative. See Appendix 6.

87. Askarel is a non-flammable liquid containing polychlorinated biphenyls (PCBs) suitable for use with Class A insulation (BS2757).

Note: Oil and synthetic insulating liquid should not be interchanged or mixed.
One large manufacturer of the liquid will be ceasing production as soon as there is an acceptable alternative product, although it is uncertain when this will transpire.

88. Askarel filled transformers should be generally to BS171 and should comply with ESI Std 35–1 wherever applicable.

89. Transformers should be of the sealed type, the tank cover being welded to the tank. Fittings will be as for oil transformers except that a pressure relief valve is required instead of a breather, and a lockable drain valve without a sampling device is required instead of a combined drain plug and sampling device.

90. Rating and diagram plates should be in accordance with ESI Std 35–1 and, in addition, a warning plate 150 mm × 100 mm made of durable and non-corroding material should be fixed in a prominent position adjacent to the rating and connection plates bearing the following wording.

CAUTION
The insulating liquid in this transformer is an askarel and contains polychlorinated biphenyls (PCBs). Great care should be taken to prevent any contamination of the environment. In the event of spillage or leakage or the need for disposal of the transformer consult Health Technical Memorandum No. 7—Electrical Services: Supply and Distribution, Appendix 6 which is displayed at the entrance.

91. Askarel filled transformers are delivered as sealed units from which there should be no escape of askarel under normal conditions. The transformer should however be examined when received for any leakage or spillage that may have occurred during transportation. Following installation periodic in-service inspection should be made for leaks. Any leaks should be reported to the manufacturer for immediate attention. As transformers should be of the sealed type, spare askarel should not be held locally.

92. There are fewer siting limitations, the transformer can be located indoors, close to working areas, or at the load centre. Normally there is no requirement for any catchment arrangement below a sealed transformer as the likelihood of askarel leakage is slight. It may however be prudent to provide some simple arrangement, e.g. bund wall or drip tray, if the transformer is located where a major leak would present a hazard to hospital users.

93. Rooms containing askarel immersed transformers should have adequate natural low level and high level ventilation to the outer air (see Appendix 1 paragraph 22–23). A copy of Appendix 6 of this document should be framed inside the entrance to any room or enclosure containing an askarel immersed transformer.

Dry type transformers

94. Dry type transformers should comply with BS171 and have Class H or Class C (BS2757) type insulation. Dry type transformers may be preferred for smaller distribution sub-stations which are incorporated in the main hospital buildings. They tend to be noisy in operation and special attention should be given to the possibility of nuisance from this cause in selecting the site of sub-stations which will employ dry transformers.

95. Resin cast insulated dry type transformers are less sensitive to moisture and adverse weather conditions than normal dry type. The resin cast insulated type of transformer is less prone to absorb moisture when de-energised or lightly loaded. The extra cost of the transformer may be justified (see paragraph 73) in certain exposed locations where there is a fire hazard.

Packaged transformer sub-stations

96. With package sub-stations the transformer is incorporated in a composite unit with the medium voltage switchboard. Such units are of compact design and consequently are space saving but they provide little flexibility for future additions to meet increased demands. Their use will mainly be confined to local distribution centres.

Outdoor sub-stations

97. Outdoor sub-stations will enable a significant capital saving to be made by eliminating the construction of a sub-station and the special fire protection requirements. Against this maintenance costs including painting and oil-sampling will be slightly higher, but on balance the use of outdoor sub-stations would be economically justified where suitable sites exist.

98. Oil immersed transformers for outdoor use should incorporate silica-gel breathers.

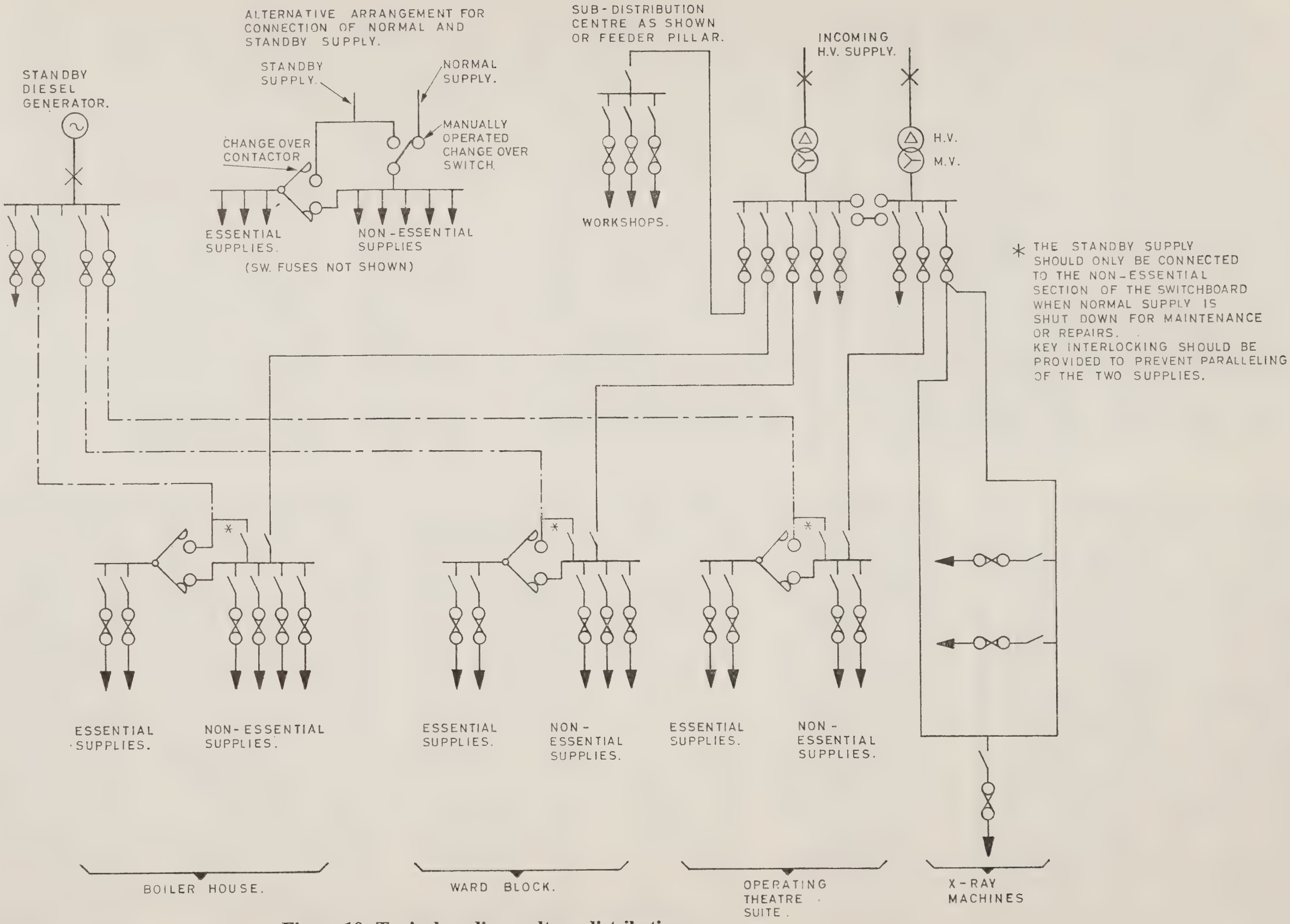

ALTERNATIVE ARRANGEMENT FOR CONNECTION OF NORMAL AND STANDBY SUPPLY.
STANDBY SUPPLY.
NORMAL SUPPLY.
MANUALLY OPERATED CHANGE OVER SWITCH.
CHANGE OVER CONTACTOR
ESSENTIAL SUPPLIES.
NON-ESSENTIAL SUPPLIES
(SW. FUSES NOT SHOWN)
STANDBY DIESEL GENERATOR.
SUB-DISTRIBUTION CENTRE AS SHOWN OR FEEDER PILLAR.
WORKSHOPS.
INCOMING H.V. SUPPLY.
H.V.
M.V.
* THE STANDBY SUPPLY SHOULD ONLY BE CONNECTED TO THE NON-ESSENTIAL SECTION OF THE SWITCHBOARD WHEN NORMAL SUPPLY IS SHUT DOWN FOR MAINTENANCE OR REPAIRS.
KEY INTERLOCKING SHOULD BE PROVIDED TO PREVENT PARALLELING OF THE TWO SUPPLIES.
ESSENTIAL SUPPLIES.
NON-ESSENTIAL SUPPLIES.
BOILER HOUSE.
ESSENTIAL SUPPLIES.
NON-ESSENTIAL SUPPLIES.
WARD BLOCK.
ESSENTIAL SUPPLIES.
NON-ESSENTIAL SUPPLIES.
OPERATING THEATRE SUITE.
X-RAY MACHINES

Figure 10 Typical medium voltage distribution

XVI. Medium voltage distribution

General

99. All distribution equipment, i.e. switchgear, fuse-boards, bus-bars, wiring and fuses should have adequate capacity for the estimated maximum loading and some spare capacity to allow for future growth. Special attention should be given to the balancing of loads between phases.

100. Switches, fuse switches, bus bars, etc. should be rated to handle safely the mpfe of the system. Where the supply is obtained from a high voltage transformer having a capacity of 800 kVA or less the mpfe of the main medium voltage system will generally be within the limits of switchgear having a 25 kA rating. The 1000 kVA transformer will probably need switchgear rated at 31·5 kA.

101. The type of distribution used will be influenced largely by the layout of the hospital and location of large loads. Maintenance of supply is particularly important and where economically practicable, use of inconnectors or ring circuits should be considered to enable the supply to be maintained in the event of a fault involving a major supply component (see paras 32 and 35).

102. A line diagram of a typical medium voltage radial distribution system is shown in Figure 10.

Voltage drop

103. Except in special circumstances, e.g. circuits for fixed X-ray apparatus (see para 111), it is important that the maximum voltage drop complies with the requirements of the IEE Regulations, in that it does not exceed $2\frac{1}{2}\%$ of the declared voltage at the remote outlet when circuits are carrying the full load current (disregarding starting conditions). Where the supply is taken from a hospital owned transformer having tap changing facilities, the circumstances specified in para 37 apply.

104. The current ratings of conductors are given in the tables of the IEE Regulations. The appropriate rating factor for close excess current protection (see para 108) may be applied where ratings are quoted for coarse excess current protection.

105. The voltage drop can be readily calculated from the conductor current rating tables included in the IEE Regulations, using the data appropriate to the type of cable used.

106. It is important to allow for any rating factors which may be applicable in respect of ambient temperature, grouping and disposition of cables or type of protection.

107. The standard ambient temperature allowed for in the tables is 30°C and a rating factor will be necessary where the ambient temperature surrounding the cables is likely to exceed this value, e.g. where wiring is installed in ducts or voids containing heating services. Where it can be established that the temperature will not exceed 25°C a rating factor above unity is permissible, e.g. where cables are laid directly in the ground the rating factor will allow a higher loading.

Circuit protection

108. Special attention should be given to the protection of circuits in hospitals, because of the increasing dependance on electrical apparatus. The rapid isolation of faulty circuits without affecting healthy circuits can be achieved using close excess current protection devices, e.g. fuse links complying with BS1361 and with BS88 Class P or Class Q1 fusing factor, miniature circuit breakers (mcb) and moulded case circuit breakers (mccb) complying with Parts 1 and 2 respectively of BS3871. Discrimination is far more difficult to achieve using coarse excess current protection devices, e.g. rewireable fuses or those having a BS88 Class Q2 or Class R fusing factor. Appendix 5 Figure 20 shows how discrimination may be achieved using close excess current protection devices of the type specified above. The curves are only typical of some of the devices available; the intention is to demonstrate to designers how discrimination can be planned.

109. Mcbs are available in current ratings up to 100A and mccbs in ratings up to 1·2 kA. It can be seen from Table 5 that the fault current handling capacity of a mcb is significantly lower than that of a BS88 fuse. In the system example shown in Appendix 5 Figure 20 for instance a M1 category mcb of 1 kA short circuit capacity would not be suitable for the 100A unit, because it could not handle the 1·5 kA resulting from a fault at Point 2. A type M1·5 of 1·5 kA short circuit capacity would just suffice but a type M3 of 3 kA short circuit capacity would be chosen as it is a type which is most readily available in the United Kingdom. A type M1 or M1·5 would not be selected for the 30A mcb because the back-up protection provided by the 100A fuse at 1·5 kA fault level is marginal; a M3 type would be chosen because it is more readily available than a M2 type which would however be suitable. As mcbs cost more than fuses, they should only be used where economically justified.

TABLE 5

Comparative fault current handling capacity of hrc fuses and mcbs.

BS88 (1967) fuses			BS3871 Part 1 mcbs		
Category of duty	Current rating A	Breaking Capacity kA	Category of duty	Current rating A	Short circuit kA
AC16	up to 500	16·5	M1		1
AC33	up to 1200	33	M1·5		1·5
AC46	up to 1200	46	M2	IN RANGE	2
AC80	up to 1200	80	M3	5–100	3
			M4		4
			M6		6
			M9		9
BS88 (1975) fuses					
Current rating A		Breaking Capacity kA			
2–1250		80			

110. The breaking capacity of the mccb range is from 10 kA to 43 kA and this approaches the breaking capacity of the fuses given in Table 5.

Fixed X-ray equipment circuits

111. The special feature of circuits for X-ray apparatus is the transient nature of the loads, a feature which can cause interference with other parts of the installation. To reduce this effect circuits supplying permanently installed X-ray equipment should be taken from separate sub-main feeders. Though comparatively heavy currents are used, the duration of the peak load rarely exceeds 1 second. There is, therefore, no problem of excess temperature rise, but it is important that the circuit wiring should be capable of carrying the maximum load without undue voltage drop. A maximum permissible voltage drop is usually specified by the makers of X-ray equipment and the sizes of the circuit conductors should be chosen to satisfy these requirements. A typical value is 5% voltage drop at the rated load.

112. Because of the transient loading of X-ray circuits considerable diversity factors can be allowed in determining the sizes of circuit wiring where several machines are to be supplied from the same sub-main cable. A diversity factor can also be allowed in determining the rating of distribution switchgear supplying X-ray circuits because the switchgear is never likely to be required to make or break the circuit under peak load conditions. Suggested diversity factors:

a. two machines:—none

b. three machines:—100% largest load plus 50% other loads,

c. more than three machines:—100% largest load plus 40% other loads.

113. The use of ring circuits will usually achieve a considerable saving in conductor size and also assist in reducing voltage drop where more than two X-ray machines have to be supplied.

114. Socket outlets for use with mobile X-rays units are dealt with in para 185. Protection of X-ray circuits is dealt with in paras 187–188.

Lift circuits

115. Because of the fluctuating nature of the lift motor loads, they should be supplied from a separate sub-main feeder to minimise the possibility of causing interference to other parts of the installation.

116. One lift in each separate section of the hospital should be arranged with an emergency "Fireman's" control at ground level (see Hospital Technical Memorandum No. 11—Emergency Electrical Services).

XVII. External medium voltage feeders

General

117. For external distribution in conduits, ducts or laid directly in the ground, the following common types of cables are in general use:

a. paper insulated, copper conductors, lead or lead alloy sheathed, armoured and served; 1100V grade (BS6480: Part 1);

b. paper insulated, aluminium conductors, lead or lead alloy sheathed, armoured and served; 1100V grade (BS6480: Part 1);

c. pvc insulated, copper conductors, single wire armoured with pvc serving (BS6346);

d. pvc insulated, aluminium conductors, single wire armoured or aluminium strip armoured with pvc serving (BS6346);

e. mineral insulated, copper sheathed (mims) heavy duty having copper conductors and sheathed with pvc outer covering (BS6207: Part 1);

f. mineral insulated aluminium sheathed (mims) heavy duty having copper or aluminium conductors and sheathed with pvc outer covering (BS6207: Part 2).

Choice of cable

118. Choice will be influenced by size, method of installation and number of terminations. With paper insulated cables special precautions are necessary with jointing which increases installation costs.

119. The choice between aluminium or copper conductors will depend on size, since the cost saving with aluminium conductors increases with size. In the size range normally required for external medium voltage feeders aluminium conductors will show a significant saving in cost and would normally be used. The weight saving with aluminium conductors facilitates installation.

120. The larger sized paper insulated copper conductor cables are more expensive than armoured pvc cables complying to BS6364 (copper conductors and pvc oversheath). The absence of a metal sheath on the pvc cable however eliminates plumbing and greatly facilitates installation where more jointing is required.

121. There is no metallic sheath with pvc cables, therefore special attention is necessary to ensure that the wire armouring has a suitable low resistance. For any armouring joint the electrical resistance should not exceed that of an equivalent length of complete armouring.

Joints

122. Straight-through and Tee joints should not be used unless economically unavoidable.

123. Paper insulated cables should be of a non-draining type BS6480: Part 1.

124. When paper insulated or mims cables are cut during installation the ends should be sealed in the manner recommended by the manufacturer. Medium voltage joints should be made in accordance with the Electricity Council Code of Practice: Engineering Recommendations C25/1.

Minimum bending radii for cables

125. The minimum internal bending radii for cables should not be less than the value appropriate to the type of cable given in the appropriate British Standard and in the IEE Regulations.

Cable supports

126. Cables should be adequately supported throughout their lengths. The minimum spacing between supports should not exceed the values given in the IEE Regulations and manufacturers recommendations.

XVIII. Medium voltage switchboards

General

127. Cubicle type boards should be designed to provide enough flexibility for future alterations and additions. They are neater in appearance than unit type switchboards.

128. The switch and fuse-gear should be capable of handling safely the mpfe of the system (see para 100).

129. Where the supply is obtained direct from a supply authority's sub-station or a medium voltage network the mpfe should be verified with the authority and the rating of the switch and fuse-gear specified accordingly.

Switchgear

130. Experience has shown that air break switches complying with BS861 and air break circuit breakers complying with BS4752 are generally satisfactory. Thus in order to reduce the fire risk, oil switchgear should not normally be used within the size range available for air break types.

131. Where a transformer supplies only one local

switchboard it will not normally be necessary to provide circuit protection on the secondary side.

Circuit protection

132. Circuit protection should be arranged to provide adequate discrimination (see paras 108–110).

Bus-bar chambers

133. Bus-bar enclosures should only be used for wiring such as that to current transformers. Bus-bars and bus-bar connections should comply with BS159 and BS158.

Aluminium bus-bars

134. Bolted or clamped joints can be made in a similar manner to joints on copper bus-bars, the recommended practices for both metals are almost identical. The following requirements should be met for obtaining a good joint:

a. the surface of the aluminium must be clean and free of oxide;

b. air and moisture must be excluded from the joint to prevent reformation of the oxide;

c. proper contact pressure must be applied and maintained.

135. Tinning the contact surface of the aluminium directly after cleaning at the manufacturing stage is a more controlled method than the application of jointing compound on assembly. The pressure contact is critical. The actual area of high pressure in the vicinity of the bolts will vary with the type of washer used but as a general guide a desirable minimum pressure is $5MN/m^2$ (800 lb/in^2). Aluminium bus-bars should only be used if the appropriate installation and maintenance standards can be achieved.

Meters

136. The supply to the main distribution centre switchboard should be equipped with an ammeter and four suitably rated current transformers together with a selector switch to enable the current loading of each phase, and of the neutral, to be selected. A voltmeter should also be specified together with a selector switch to enable the voltages between each phase and neutral to be selected.

137. Kilowatt hour meters should be suitable for unbalanced loads and comply with BS37. The use of these for individual departmental costing would need to be justified. Indicating instruments should comply with BS89 industrial grade, 100 mm dial instruments are normally considered satisfactory. Current transformers for use with instruments should comply with BS3938.

Sub-distribution centres

138. Sub-distribution switchgear and distribution boards should be situated so as to minimise the length of circuit wiring. Switch and fusegear enclosures should be well ventilated and accessible. The enclosure must not be used for any other purpose and should have adequate fire resisting separation at floor and ceiling levels and with any corridor or staircase forming a recognised form of escape. Distribution fuseboards should, where practicable, be situated to enable access from a standing position (see Appendix 2).

139. All individual switches, fuse-switches and fuseboards should be clearly and indelibly labelled to indicate the circuits controlled or parts of the hospital supplied. As far as is practicable a standard form of labelling should be used throughout the installation.

140. Sub-distribution enclosures should be fitted with locks to prevent unauthorised interference, the locks being common throughout the installation. Where distribution equipment is not in a separate enclosure or locked switchroom a lock should be fitted to every distribution board and provision made for locking the isolating switch controlling that fuseboard. Spareways and fuses should be provided and space allowed for future additional units.

Feeder pillars

141. In general, particularly in new hospitals, it will be possible to make indoor facilities available to house sub-distribution equipment. Instances may arise, however, where it will be convenient and economical to employ outdoor feeder pillars where a feeder is used to supply several peripheral buildings, e.g. staff accommodation or workshops.

142. Details of cable terminations, bus-bars and safety arrangements (including the shielding of bus-bars and live connections and, where necessary, anti-condensation heating) should be covered by specification.

XIX. Internal medium voltage distribution and utilisation circuits

General

143. The type of cable selected should be suitable for the ambient conditions in which it is to be installed, special attention being given to temperature, risk of mechanical damage, ease of installation and facility for subsequent alterations and additions as far as is reasonably practicable.

144. Fire precautions are of special importance in public portions of hospitals and particularly in areas

where patients are housed. Another important aspect is the need to minimise electrical interference which will affect the use of sensitive electro-medical apparatus. These two important aspects demand that all wiring shall have a continuous metallic sheath or be enclosed in steel conduit or trunking which is electrically continuous and bonded to earth (see para 201). Associated phase and neutral conductors should be installed in the same earthed enclosure.

145. Due to the need to minimise electrical interference, systems of wiring such as earthed sheath return wiring (esrw) and protective multiple earthing, must not be used in hospitals. With such systems, return neutral currents may flow along any metal work offering a path to earth and cause widespread magnetic fields. The abatement of electrical interference is dealt with more fully in Hospital Technical Memorandum No. 14—Abatement of Electrical Interference.

146. In damp situations special precautions should be taken where metal cable sheaths, metal conduits and fittings and trunking systems are likely to come into contact with any of the following:

a. materials containing magnesium chloride which are used in the construction of floors and dadoes;

b. plaster undercoats contaminated with corrosive salts;

c. lime, cement and plaster, e.g. on unpainted walls;

d. oak and other acidic woods;

e. dissimilar metals liable to set up electrolytic action.

147. Application of bitumen or bitumenised paint before assembly is an effective precaution against corrosion.

148. In residential accommodation and areas where apparatus sensitive to interference is not used (see paras 144–145) normal domestic type installations are satisfactory, e.g. non-armoured pvc insulated pvc sheathed wiring complying with BS6004 provided it is protected against the possibility of mechanical damage as required by the IEE Regulations.

Internal feeders

149. Paper insulated, pvc insulated or mims cables are suitable for internal feeders. Paras 117–126 on external feeders apply equally for internal distribution. Serving on paper insulated cables will not be required except in damp and corrosive atmospheres. Should serving be considered necessary on internal feeders pvc serving should be used. Compounded fibrous types of serving are highly flammable and should not be used internally. This type of serving should be removed from external feeders at and from the point of entry into buildings.

150. At intersections and junctions of routes, cables should be labelled for identification with permanent oil proof labels.

Bus-bar trunking systems

151. Because of their superior fire resisting properties, bus-bar trunking systems are particularly suitable for rising mains.

152. Appropriate current ratings and voltage drop values are given in the IEE Regulations. For a given current rating, aluminium conductors are cheaper than copper conductors and are only about half the weight. The weight factor is a particular advantage with vertical feeders. The extra rigidity of aluminium is advantageous in the smaller sizes (see para 155).

153. Plug-in type bus-bar systems are available which enable connections to be made and broken whilst the bus-bars are energised, but for normal hospital applications this facility will not be required and permanent connections will be satisfactory.

154. Higher operating temperatures are permissible with bus-bar systems. It is important that the insulation of cable terminations and connections to bus-bars is suitable for the maximum operating temperature of the bus-bars or is removed to a distance of 150 mm as required by the IEE Regulations.

155. Smaller copper conductors (e.g. those less than 10 mm dia) should be sleeved throughout their length, but sleeving can usually be omitted from larger copper conductors and from aluminium conductors.

156. Where long horizontal bus-bars are used they should incorporate expansion couplings at suitable intervals to allow the bar to expand in both directions. The maximum straight length of bus-bar which is permissible without an expansion coupling will vary with different types of support and should be in accordance with the manufacturer's recommendations.

157. The spacing of insulators along the conductors should suit the mpfe of the system. Spacings of 0·6 m are typical and should be suitable for fault currents which are liable to be experienced with medium voltage systems supplied from transformers up to 800 kVA.

158. Special attention should be given to earth continuity of trunking housing bus-bars because of the mpfe. Trunking which houses bus-bars having a current rating exceeding 200A should have a continuous tinned copper bonding strip with bonding links at the joints of the trunking. The cross-sectional area of earth continuity conductors relative to the largest associated circuit conductor should comply with the values given in the IEE Regulations.

159. Non-flammable fire barriers should be inserted in trunking where it penetrates floors and partitions which are themselves intended to form fire barriers.

Mineral insulated metal sheathed cables

160. Mineral insulated cables are available with copper conductors and copper or aluminium sheaths.

Cables with aluminium conductors are also available but they always have aluminium sheaths. Cables having copper conductors and sheaths should comply with BS6207: Part 1 and cables having copper or aluminium conductors with aluminium sheaths should comply with BS6207: Part 2. There are two grades namely 600V, light duty and 1000V, heavy duty.

161. The chief advantage of mims cables is their ability to satisfactorily withstand higher or lower temperatures than alternative types. There is a cost saving with aluminium conductors and sheaths which is a significant factor with larger sizes. Aluminium is lighter and consequently easier to install.

162. The smallest aluminium conductor specified in the British Standard is 16 mm^2. Aluminium sheaths are less resistant to corrosion than copper; because of this factor where aluminium sheathed cables are used they should have an extruded pvc outer covering. Aluminium sheathed pvc served cables are not recommended unless a high standard of installation can be achieved.

163. All tails should be sleeved with insulation suitable for the operating temperature and colour coded to indicate polarity and phase as appropriate.

164. Where single core cables are used for heavy current circuits, cables of different phases should be laid in close proximity (preferably in trefoil formation) and other appropriate steps taken to reduce eddy currents e.g. by the use of non-ferrous fittings at terminations, or by making slots between the hole and the outer edge of any ferrous plates through which the cables pass.

165. Cable trays can simplify installation where several cables are to be installed in close proximity. They should have a rust resisting non-metallic finish in order to reduce the risk of damage by electrolytic action (e.g. two coats of bitumastic paint).

166. The powder type mineral insulation used readily absorbs moisture and it is important that the correct seals, fittings and accessories as supplied by the manufacturers are used. It is also advisable to use the special installation tools supplied by the manufacturer and to follow their advice concerning the use of temporary sealing during installation.

Cables in conduits or trunking

167. The grades of cable normally used are pvc cables complying with BS6004 or butyl or ep rubber cables complying with BS6007. Experience has shown that pvc insulated cables which have superior mechanical properties, are preferable for ambient temperature conditions within the range 0–65°C, and are therefore, suitable for most hospital applications.

168. Butyl and ep rubber cables are suitable for ambient conditions up to 80°C and their use would normally be restricted to situations where temperatures up to this limit are likely.

169. Silicone rubber insulated cables complying with BS6007 are suitable for use in temperatures up to 145°C. In general, however, uses for silicone rubber insulated cables will be rare because mims cables will usually be preferred where high ambient temperatures are likely.

170. Cables installed in steel conduit sizes 20 mm or 25 mm or in steel trunking (where there are sufficient circuits to justify its use) will usually represent the most economical type of installation. Trunking has the advantage of facilitating subsequent alterations and additions, sufficient space should be allowed for this. Conduits smaller than 20 mm should not normally be used.

171. The number and size of cables in any conduit should not exceed that specified in the IEE Regulations. The conduit system for each distribution board should be kept separate and cables from different distribution boards should not normally be enclosed in the same conduit.

172. Conduit should be heavy gauge quality to BS31, or BS4568 Class B. Enamel finish is satisfactory for dry situations. Galvanised quality should be specified where damp conditions are likely. All conduit threads exposed after installation should be coated with a rust-resisting paint.

173. As far as is practicable conduits should be continuous between outlets. Factory made bends, tees, etc. should not be used. Conduit fittings should be of malleable cast iron to BS31 or BS4568.

Under-floor steel trunking and duct systems

174. Under floor trunking and duct systems are usually more expensive than alternative methods of installation (e.g. buried conduits or overhead trunking). There is also a greater risk of damage caused by water entering inspection covers of under-floor systems. It is therefore recommended, that this system should not be used where there are other suitable alternative methods.

175. In certain departments e.g. radiotherapy and diagnostic X-ray it may be necessary to run a continuous duct or trunking within the floor of the main treatment rooms between the operating panel and the apparatus, routed to avoid main and scatter beams. It is important that the route of this trunking is agreed before architectural and structural designs are finalised.

176. Where drawing-in cables is necessary, the space factor of wiring in ducts should not exceed 35%, to comply with the IEE Regulations.

Cable trunking

177. Cable trunking represents the cheapest type of installation where a number of circuits can conveniently follow the same path. Cable trunking is suitable for use in voids, above suspended ceilings, surface applications and in vertical ducts. Trunking layouts should be predetermined and be dimensionally co-ordinated with other building components to enable standard prefabricated lengths to be used whenever practicable.

178. Complete segregation of normal and emergency sub-circuit wiring may not be justified in all instances. In the most important areas where the emergency installation will include a number of sub-circuits, it will be a comparatively simple matter to separate these circuits from the wiring of non-essential circuits. In other areas where only a small part of the sub-circuit wiring is connected to the emergency part of the installation, the additional expense of segregating the emergency sub-circuits from non-essential sub-circuits would not be justified. Safety lighting circuits on primary escape routes should, however, always be segregated from non-essential wiring. A convenient method of achieving this is to use mims cable. Where circuits serving safety lighting in one fire compartment pass through another fire compartment mims cable must be used. Lighting and power circuits can be installed in the same conduit or trunking. Extra low voltage wiring can be installed with wiring operating at mains potential providing its insulation is suitable for the maximum voltage present.

179. Cables installed in trunking should be laced or clipped together in convenient groups at suitable intervals and labelled to assist identification of circuits. The number and size of any cables in any trunking should not exceed that allowed in the IEE Regulations.

180. Trunking should have a suitable anti-rust finish (e.g. zinc-coated sheet steel with stove-enamel finish). For damp situations, galvanised trunking should be specified.

181. Jointing surfaces should be free of enamel finish to ensure satisfactory earthing continuity between sections. On sizes larger than 75 mm × 50 mm, copper bonding links should be used.

Fire alarm circuits

182. As the main purpose of a fire alarm system is to give an early warning of a fire, wiring in conduit and trunking will be satisfactory. There is not a special requirement for the use of mims cable although this is often more convenient than wiring in conduit and trunking. General requirements for fire alarm circuits are included in Hospital Technical Memorandum No. 16—Fire Precautions.

General socket outlet sub-circuits

183. 13 amp socket outlets complying with BS1363 arranged on ring final sub-circuits should be used as a standard throughout hospitals for connecting portable or mobile mains voltage equipment to the supply. The allocation of socket outlets in specific departments is dealt with in Hospital Building Notes covering those departments. Generally, the allocation of socket-outlets in corridors should facilitate the use of electrically operated cleaning machines assumed to have flexible cords 9 m long.

184. The standardisation of socket outlets throughout hospitals is considered to be of great importance. There have been instances of delays occurring with serious consequences because the plugs on electro-medical equipment did not match the socket outlets provided in particular treatment areas. This matter is of special importance when major alterations or extensions are being carried out to existing hospitals and appropriate steps should be taken to standardise sockets throughout the old and new sections.

Sub-circuits and socket outlets for use with mobile X-ray units

185. To ensure that the full rated output of mobile X-ray units is available during the exposure period, manufacturers recommend a maximum value for the supply impedance at any socket outlet to which the unit may be connected. 0·34 ohm is a typical value for the 300 mA set. The IEE Regulations specify that the maximum voltage drop for normal purposes shall not exceed 2·5% (6V where the declared voltage is 240V). Although ring sub-circuits are rated at 30A it is unlikely that they will be loaded to this value. An allowance of 20A per ring would be a generous allowance under these conditions, the maximum impedance of the distribution circuits to any socket outlet would not exceed 0·30 ohm if the installation complies with the maximum voltage drop requirement of the IEE Regulations. In practice, the impedance of the main and sub-main feeders will be less than that of the ring sub-circuit and the total impedance between the intake and any socket outlet should be less than 0·30 ohm with a correctly designed installation. To this value must be added the impedance of the supply authority's mains feeding the hospital. This will vary according to the supply arrangements but can reasonably be assumed to be between 0·02 and 0·05 ohm. Accordingly provided the voltage drop requirements of the IEE Regulations are complied with, the total source impedance at any socket outlet can be expected to be less than 0·34 ohm. A total source impedance of 0·34 ohm should be used as a designed value, making suitable allowance for future extensions. This assumes an impedance up to the local distribution boards of 0·10 ohm. The remaining impedance to the mid point of the ring sub-circuit or at the end of a spur would be 0·24 ohm. Table 6 gives the maximum length of ring circuits using single copper conductor cables.

TABLE 6

Maximum length of ring circuits using single core copper conductors.

Size of copper conductor	Resistance ohm per m	Total maximum length of ring
2·5 mm²	0·008	60 m
2·5 mm² mims	0·0085	56 m
4·0 mm²	0·005	96 m

186. The energy dissipated in the cables during a maximum exposure can be readily calculated and will be seen to be quite negligible because of the very short duration of the heavy current flow and consequently will be insufficient to cause undue deterioration of the wiring. Rigorous tests and subsequent experience have shown that standard 13A switched socket outlets can satisfactorily withstand these momentary heavy currents. It is unlikely that the switches at the socket will be operated during the exposure periods.

187. In addition to ensuring satisfactory voltage drop arrangements where mobile X-ray units are energised from standard general purpose socket outlets it is necessary to ensure that the close current protection of the circuits (see para 108) will not operate under normal operating conditions, e.g. during the brief heavy current exposure period.

188. Class Q1 fuses complying with BS88 and thermal/magnetic type mcbs are suitable for protecting 30A ring circuits when used for supplying mobile X-ray units up to 300 mA rating.

189. One type of 30A magnetic/hydraulic mcb and some class P fuses (BS88) are not satisfactory for this application as they are liable to operate during exposures at the maximum rating of the X-ray units.

190. Mobile X-ray units fitted with 110/·0076 in. (0·0048 in.²) flexible cords can utilise a standard plug complying with BS1363, having a screw down type cord grip and engraved "X-ray only". The fuse in this type of plug when used with mobile X-ray units should be replaced by a solid link. The length of the cord must not exceed 15 ft. A special unfused plug marked "X-RAY" is available for connecting mobile X-ray units with 97/·012 in. (0.01 in.²) flexible cable. The length of this cable must not exceed 30 ft. Equivalent metric leads are, flexible cable: 30 ft. of 97/·012 in. equals 7 m of 84/0·3 mm (6 mm²), flexible cord 15 ft. of 110/·0076 in equals 5 m of 56/0·3 mm (4 mm²). As the 4 mm² flexible cord cannot be satisfactorily accommodated in the standard 13A plug, the special unfused plug marked "X-ray" must be used for both sizes of metric lead.

191. Socket outlets which are extensively used for mobile X-ray units up to 300 mA rating should be engraved "X-ray". Additionally a small indelibly marked self adhesive label should be attached to the socket outlet to indicate the supply impedance to that point. Details of the measurement and marking of socket outlets for use with mobile X-ray units is given in Appendix 7.

Supplies for high shock risk areas

192. A portable appliance which is connected to the mains and used in close proximity to earthed metalwork and/or electrically conducting type floors can constitute a significant shock risk (e.g. in service voids, boiler houses and plant rooms). The risk can be reduced considerably by using either a step-down or mains isolating transformer to energise the appliance. This should not however require a permanently installed central transformer supplying socket outlets which differ from the standard referred to in paras 183–184.

193. In high shock risk areas, handlamps can be fitted with safety plugs complying with BS1363 and BS3535 (Safety Isolating Transformers). The plug fits the standard socket outlets and incorporates a double wound 240/25 volt transformer with the secondary centre-tapped to earth and having a typical rating of 40 VA, which would be sufficient for a handlamp.

194. In high shock risk areas, standard mains voltage class 1 (earthed) hand tools can be fitted with plugs which fit the standard socket outlet, on an inexpensive earth-free supply unit. Figure 11 shows the schematic arrangement of such a unit. Relay A operates at 1 mA and a person making contact with one of the lines and earth would pass a maximum current of 3·5 mA, in which event the supply would be interrupted until the unit is manually reset. A typical rating for such a unit is 500 VA, which would be sufficient for most hand tools. The mains input lead to the unit should be kept as short as practicable.

195. Electro-medical apparatus and patient safety aspects are dealt with in Hospital Technical Memorandum No. 8—Safety Code for Electro-medical Apparatus.

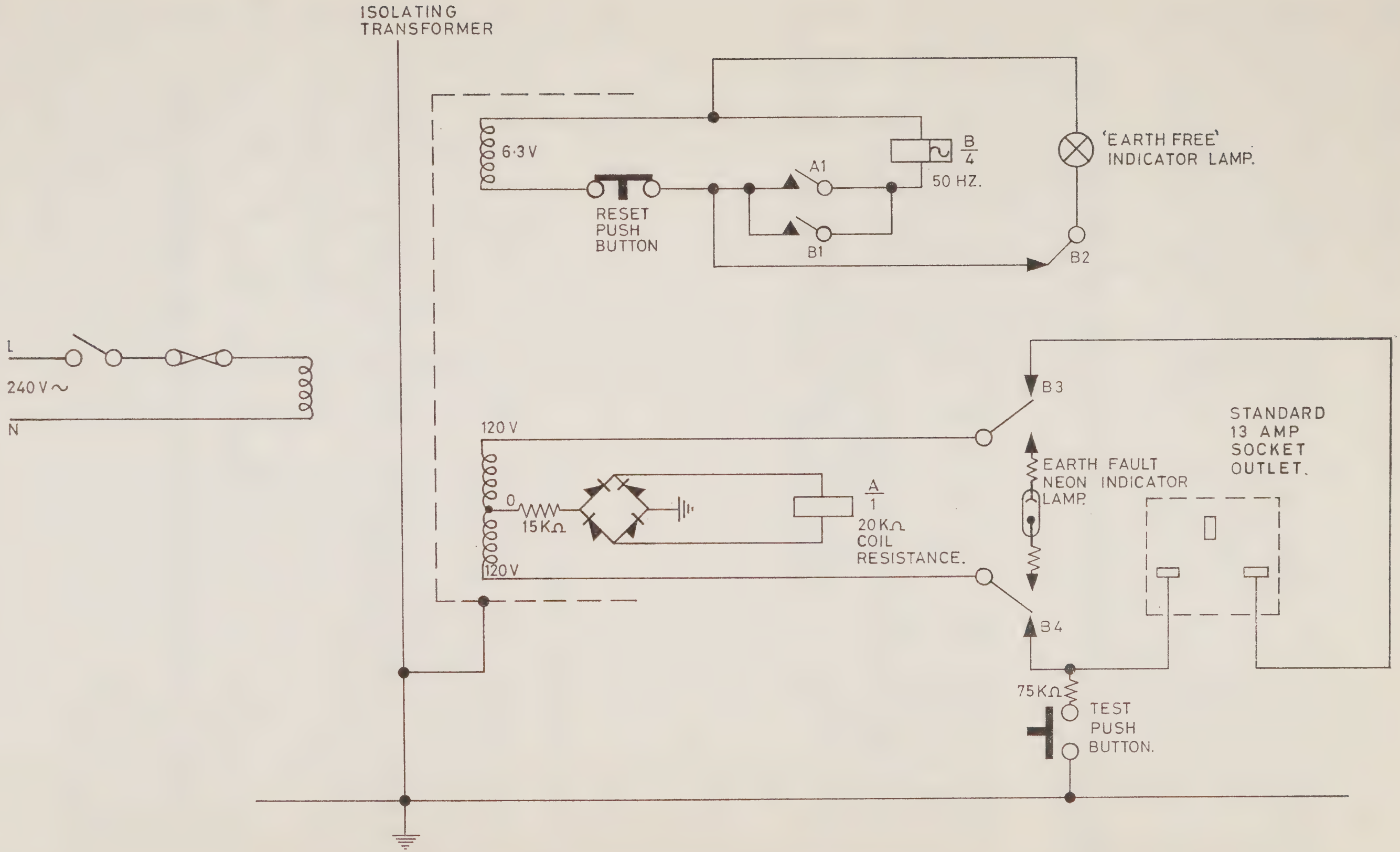


Figure 11 Schematic diagram of an earth free supply unit

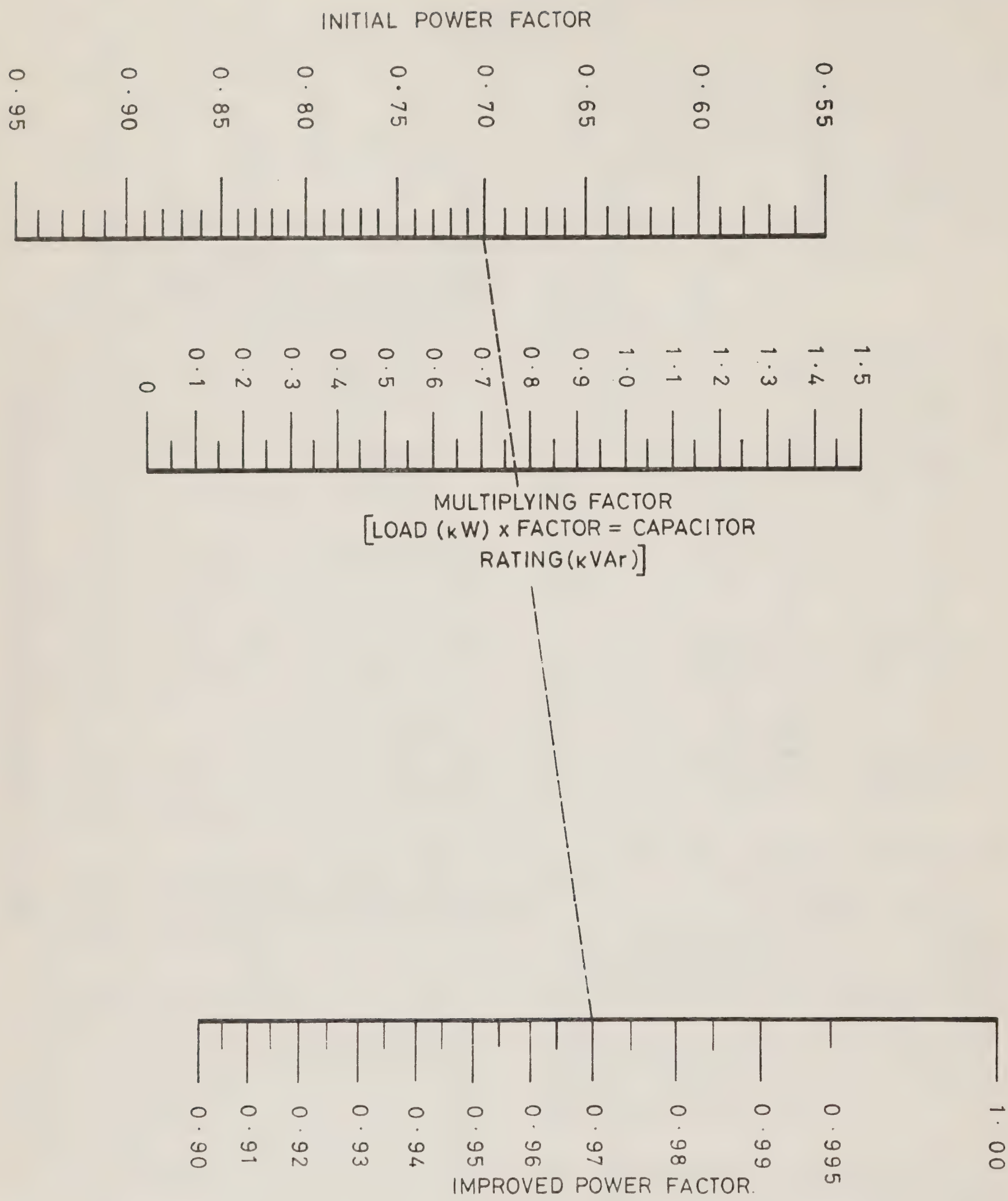


Figure 12 Chart for use in determining a power factor improvement capacitor rating

XX. Power factor improvement

196. Typical overall power factors in hospitals range between 0·85 and 0·95 lagging. Where a maximum demand charge is specified in kVA it may be economic to provide power factor improvement equipment. It may also be economic where the maximum demand charge is specified in kW, if there is an additional charge for a low power factor. The value at which this charge is levied varies from one supply authority to another.

197. Capacitors used for power factor improvement should comply with BS1650. Askarel-immersed power factor improvement capacitors should be of the sealed type, fitted with a warning plate similar to that specified in para 90 but substituting "capacitor" for "transformer". General guidance on askarel filled apparatus is given in paras 86–93. A copy of Appendix 6 of this document should be framed inside the entrance to any room or enclosure containing an askarel immersed power factor improvement capacitor.

198. Where capacitors are installed care should be taken to eliminate the possibility of an overall leading power factor during periods of light load.

199. Power factor improvement at individual motors has the advantage of reducing the voltage drop in the cable supplying the motor. When matched to the full load motor kVAr the possibility of excessive improvement is eliminated. Capacitor(s) may be connected directly to the motor terminals. Generally this will not affect the run-up of normal running of the motor provided the kVAr rating of the capacitor(s) does not exceed 90% of the full load motor kVAr where direct-on-line or rotor resistor starting is employed (85% if star-delta or autotransformer starting is employed). It is advisable to check this with the motor manufacturer. It will not be economic to apply individual improvement to every motor regardless of size.

200. Figure 12 can be used as an aid in determining the capacitor kVAr rating required for power factor improvement to specific values. For example, the dotted line on this nomogram shows that for an initial power factor of 0·7 to be improved to 0·97, the required kVAr is 0·77 × kW load. Hence for a 75 kW load the capacitor rating would be 58 kVAr. Although individual loads might have power factors as low as 0·7, typical overall power factors in hospitals are in the range specified in para 196.

XXI. Earthing

General

201. When the hospital supply is at medium voltage the supply authority will usually provide a main earthing terminal for use with the hospital electrical installation. In an installation where a standby generator is present an independent earth system should be provided to cater for any loss of the supply authority earth. A separate earthing system is also necessary when the supply is taken at high voltage. The earth impedance must satisfy the basic earthing requirement of the IEE Regulations which require that the earth fault current will operate the largest protective device.

Earth electrodes

202. To ensure the required earth impedance, electrodes should be buried in the ground at a position as near as is practicable to the sub-station or main distribution centre but not less than 3 m from the base of the building. The extent of the electrode system required will depend on the soil resistivity. A typical electrode would consist of steel cored copper rods 12 mm diameter and 3 m long. Where more than one rod is required the rods should be spaced apart by a distance at least equal to the length of the rods and they should be connected in parallel.

203. Initially it is recommended that one electrode be installed and the impedance measured as described in an appendix to the IEE Regulations. Provided the rods are spaced apart as stated above, the overall impedance will be approximately equal to the impedance of one rod divided by the number of rods employed. In this way the number of rods required to achieve a specific impedance can be determined. The impedance of the final electrode system should be verified by an earth-loop impedance test.

Earth connections

204. Connections to earth electrodes should be made with a suitable clamp, e.g. a split or claw type non-zinc bronze with cable sweating socket. The connections and associated connecting cable should be buried at least 0·6 m in soil, and protected with cable tiles. Buried earthing connections should be protected from corrosion by a suitable compound and should be reasonably accessible for inspection. Terminations of connecting cable should also be protected against corrosion.

Main earth bus-bar

205. It is usually desirable to have a main earth bus-bar in the transformer chamber or medium voltage switchroom with connections as follows:—

a. bare conductors to transformer frames;

b. bare conductor to high voltage switchgear frame;

c. bare conductor to medium voltage switchgear frame;

d. insulated stranded conductor to sub-station earth electrode(s);

e. insulated stranded cable to medium voltage switchboard neutral bus-bar.

206. The minimum size of earthing leads and earth continuity conductors relative to the size of the largest associated circuit conductor should not be less than the value given in the IEE Regulations.

207. Figure 13 shows a typical sub-station earthing system. British Standard Code of Practice CP1013 deals with various aspects of earthing.

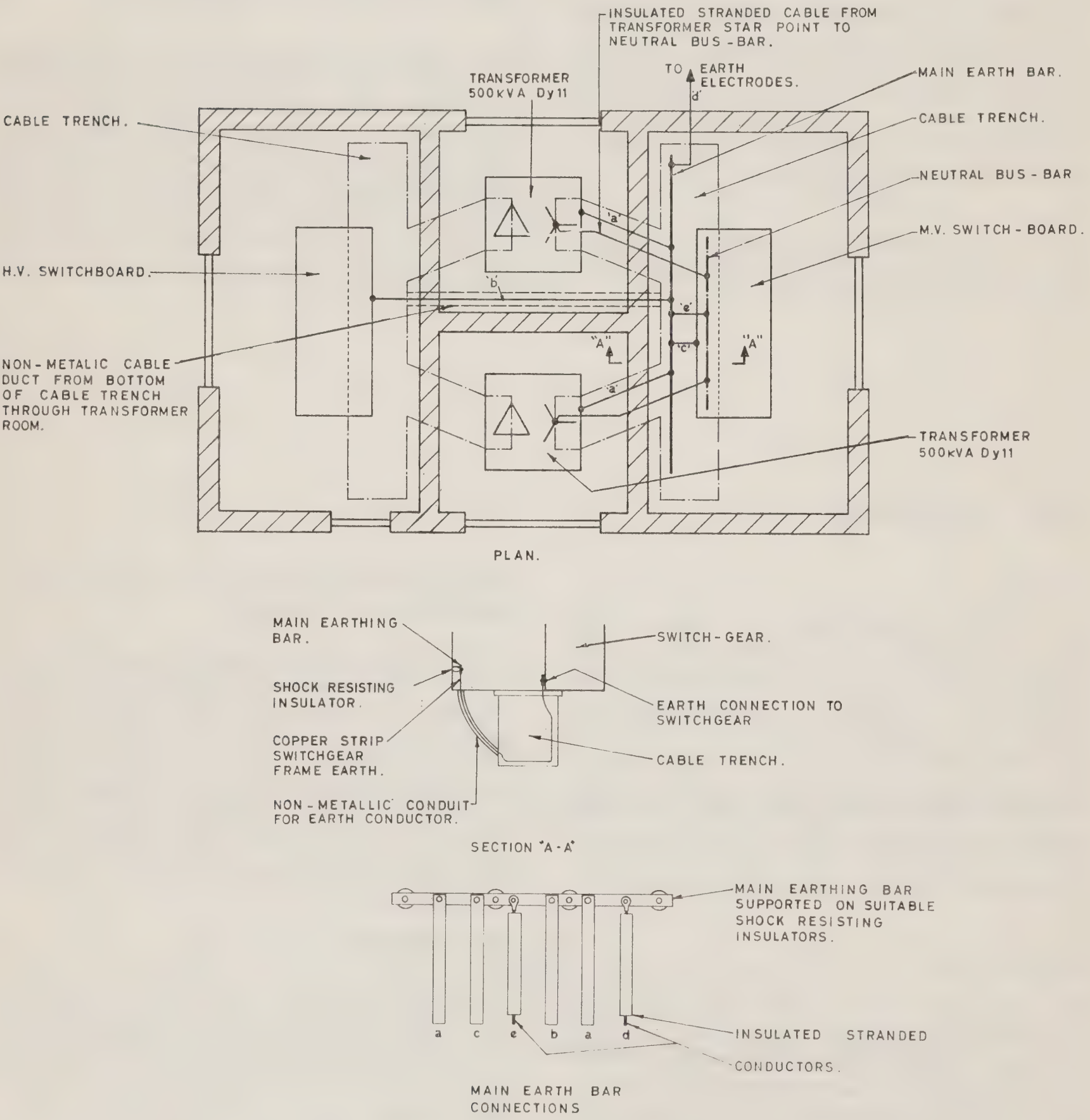


Figure 13 Sub-station earthing

XXII. Lightning protection

208. Whether or not lightning protection is justified will depend on the height of the buildings and the location of the hospital as some areas are more prone to lightning than others. British Standard Code of Practice CP326 includes a point allocating system which is intended as a guide in determining whether or not a particular building should have lightning protection. Using this system, it will usually be found that main hospital buildings will require protection. Other ancillary buildings (not used for patient accommodation) need not be separately protected. Frequently they will come within the protection zone of nearby taller buildings having protection.

209. Recommended details of a lightning protection system are given in Appendix 4.

XXIII. Record drawings and maintenance manuals

210. A copy of each working drawing, including wiring diagrams of special equipment together with operational and maintenance manuals of plant and specialised equipment supplied under the contract are required. The drawings should be amended to incorporate any alterations which have been made during the installation to provide an accurate record of the completed installation. Routes of buried cables "as laid", positions of joint boxes, multiple cable ducts with details of spare ways within ducts should be shown accurately on the drawings.

XXIV. Handing over procedure

211. When the installation has been completed in accordance with the contract, a take-over certificate will be issued certifying the date on which the installation was taken over and the commencement of the maintenance/defects liability period.

212. There should be a formal procedure which should include a thorough inspection of the installation to assess the quality and accuracy of the work and the witnessing of any tests specified in the contract by the engineer responsible for supervising the work and a representative of the electrical contractor. The engineer representing the hospital and the architect (where applicable) may be invited by the engineer supervising the work to witness tests and inspections and attend at hand-over.

213. Lists of any minor defects or deficiences relating to the work carried out by the electrical contractor should be compiled with the take-over certificate. Retention moneys as determined in the contract should be paid over at the satisfactory rectification of the defects or deficiences. This should also cover items provided by nominated suppliers.

214. Wiring diagrams, instruction manuals, etc. should be given to the engineer supervising the work, ideally at the time of hand-over but no later than at the end of the defects liability period.

215. Commissioning is dealt with in Hospital Technical Memorandum No. 17—Commissioning of Hospital Engineering Services and the associated Commissioning Manual No. 6 deals with electrical installation.

Appendix 1

High Voltage Sub-stations

Siting

1. Although it is desirable to site sub-stations as near as possible to the load centre to be served, it is also necessary to consider the fire risk to other parts of the hospital and nuisance from noise. Whenever practicable sub-stations should not be located in main hospital buildings and should be far enough away from wards and operating theatre suites to avoid any possibility of noise nuisance.

2. Where practicable, transformer sub-stations should be installed at ground floor level; oil immersed transformers should only be installed at ground level. Because of restricted access for fire fighting and the possibility of flooding, basement sites should be avoided.

Access

3. Sub-stations should be accessible from a road to allow easy access for transformer changing, fire appliances, maintenance vehicles, etc. There are restrictions on access to High Voltage sub-stations (see Hospital Technical Memorandum No. 21—Safety Code for High Voltage Installations).

Layout

4. The layout should allow adequate space for drawing-in and terminating cables and for servicing purposes. The size of the sub-station should be related to the anticipated total development, either by allowing space for future additions or by locating and designing the sub-station so that future extension is possible. Headroom should be sufficient to ensure adequate cooling. Typical layouts are shown in figures 14–17.

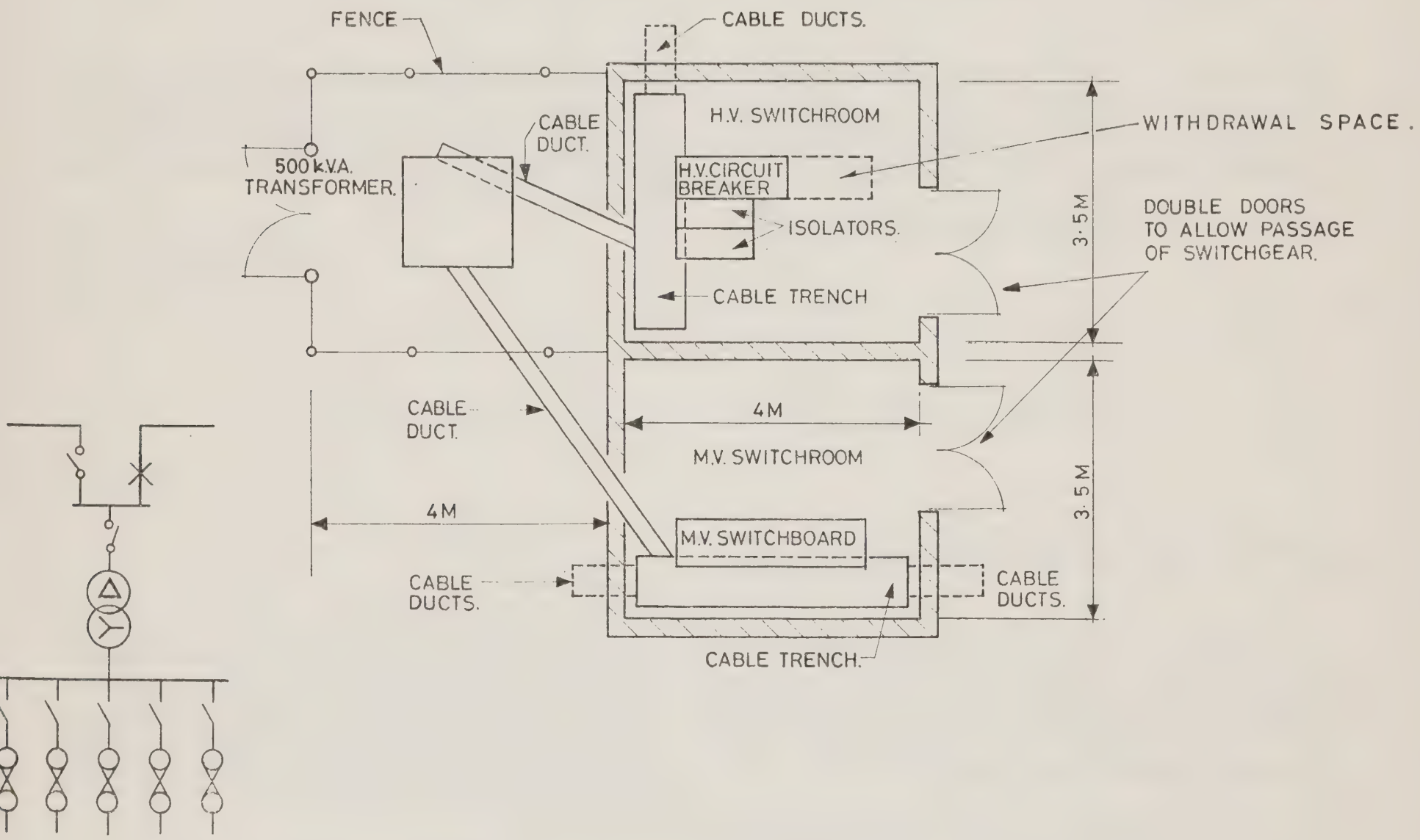


Figure 14 Small sub-station with outdoor transformer and high voltage ring main unit switchgear

5. It is not necessary to provide sufficient headroom and a lifting beam to facilitate the removal of a transformer from its tank whilst inside the chamber. With the present day reliability of transformers it should rarely be necessary to do this; if it is, the transformer can be moved into the open air and a crane used. The cabling and ducts should be so arranged as to avoid obstruction to the removal of the transformer.

6. The following minimum clearances are recommended:

Between adjacent transformers	—1·2 m
Between transformer and wall	—1 m
Headroom above transformer tank	—1·6 m
Headroom above switchgear	—0·9 m

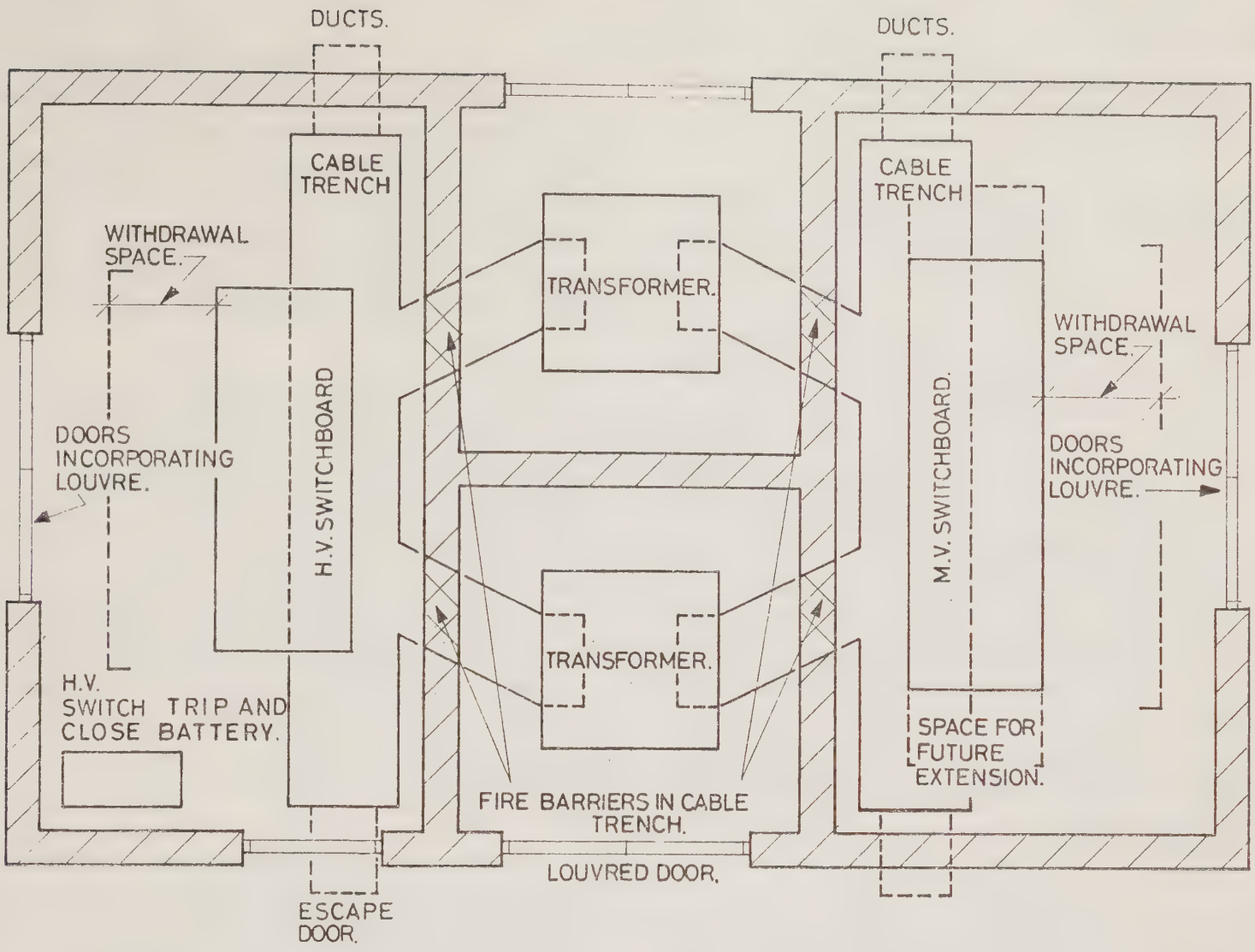


Figure 15 Sub-Station with HV ring main switchboard, two transformers and medium voltage switchboard cubicle type

Between rear of HV and MV switchgear and wall	—0·8 m
Between front of HV switchgear and wall	—1 m plus 1 m for forward withdrawal switchgear

7. As far as is practicable all equipment should be accessible from floor level. Where equipment which is liable to require servicing is above normal reach, permanent access facilities should be provided (e.g. a fixed hard wood stand).

Construction

8. The following minimum construction requirements are suggested:

a. Walls and fire-resisting partitions forming the chamber—230 mm brickwork, or equivalent fire resisting construction. Internal walls should have a suitable finish to reduce dust formation and facilitate cleaning.

b. Floors and ceilings—125 mm re-inforced concrete or equivalent fire resisting construction. Floors should have a non-slip, dust reducing finish.

c. It is unnecessary to incorporate a weak panel for explosion relief. Doors should open outwards and the width of the opening should allow sufficient clearance for transformers and should be of half hour fire resisting construction.

d. To minimise solar heat gain, windows should not be provided in transformer chambers.

Oil retaining arrangements

9. Transformer chambers which will house oil-immersed transformers should have retaining walls or similar provision, finished to prevent oil spreading in the event of leakage. Retaining arrangements should be capable of holding more than the total oil content of the transformers and are preferable to underground oil pits. The retaining arrangements should not impede the removal of the transformer.

10. Switchrooms should have a slight fall in the floor or other similar provision to prevent oil spreading beyond the chamber.

Ducts

11. Cable trenches and ducts should be so constructed as to avoid providing paths along which leaking oil will travel.

12. They should have a fire-resisting barrier (e.g. sand blocks) where they pass beneath walls and partitions which themselves form fire resisting barriers between parts of the building.

13. External cable ducts should be sealed where they enter buildings to prevent ingress of water and vermin.

Fire protection

14. The fire risk associated with good quality oil circuit breakers and transformers is slight, but it is important that reasonable precautions are taken to prevent the spread of fire. In addition to the fire resisting separation between transformer chambers and switchrooms, there should be adequate fire resisting separation between these areas and adjoining parts of the hospital. Where this cannot be arranged, fixed automatic fire-extinguishing apparatus should be provided. Fixed fire extinguishing equipment need not be provided where each transformer is housed in a separate cell of fire resisting construction or where high voltage switchgear units are separated by suitable fire resisting partitions.

15. High voltage and medium voltage cables should be installed in separate ducts or conduits with adequate fire resisting separation between them, and fire resisting separation should be provided between medium voltage feeders where two or more transformers are installed. Tripping circuit cables which are external to breakers should be resistant to fire damage from any other cables. The flammable serving should be removed from cables at the point of entry to and within the building to reduce the fire risk. Exposed portions of cable insulation should be wrapped with a suitable tape as additional fire and mechanical protection.

Fire extinguishing apparatus

16. Transformer chambers housing more than one oil-cooled transformer, and high voltage switchrooms without fire-resisting separation between the switch units, should be equipped with CO_2 fire extinguishing installations arranged with fusible links and have facilities for manual operation. A separate installation should be provided in each room requiring protection. Each room requires a warning notice, see para 29.

17. Fusible links having an operating temperature of 68°C should be placed at ceiling level over each transformer and over each switchgear bank and should be arranged to operate a CO_2 release valve and a switch connected with the hospital fire warning system. The link lines should consist of non-ferrous flexible cord installed in 20 mm galvanised steel conduit. A safety device should be provided to prevent inadvertent operation when the chamber is occupied and a conspicuous notice should be provided drawing attention to this.

18. A manual release should also be provided which should be housed in a glass-fronted box mounted outside the access door to the chamber. It should be painted red and its use clearly indicated.

19. The cylinders of liquified CO_2 should comply with BS401 and should be mounted vertically in a suitable rack located outside the fire risk area.

20. The quantity of CO_2 should be on the basis of one 45 kg cylinder for each 45 m^3 of room volume to be protected.

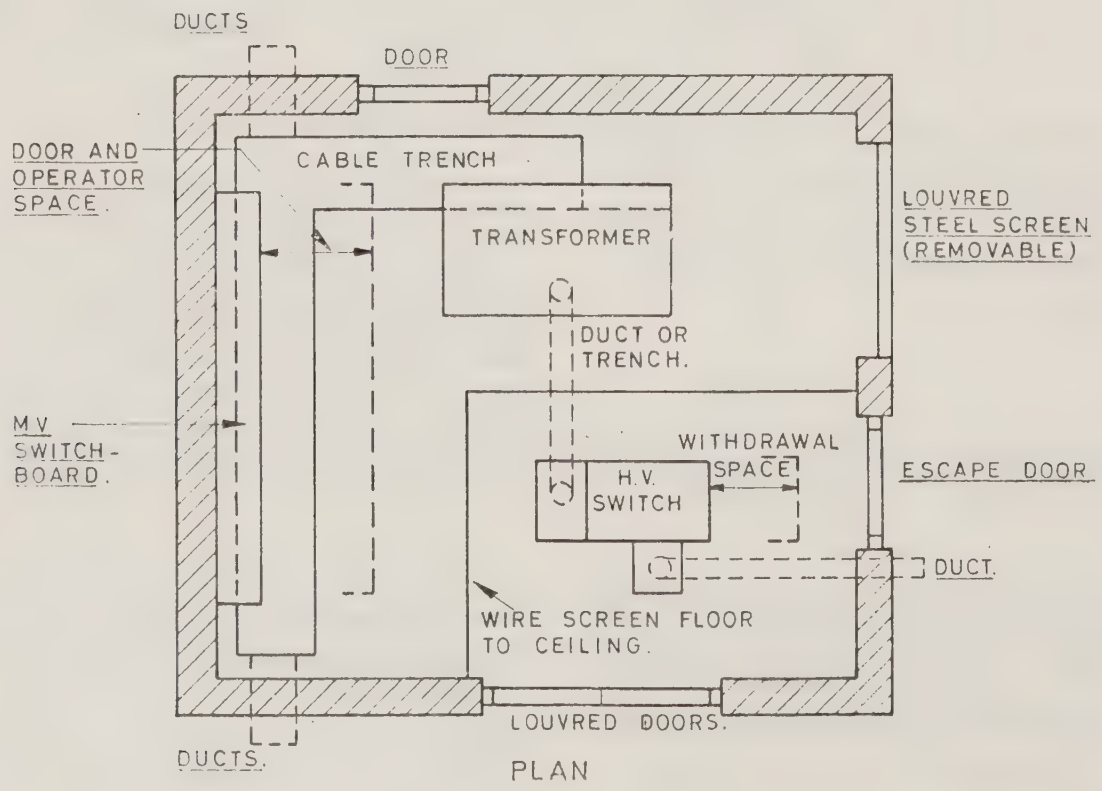


Figure 16 Sub-station with single HV switch, single transformer and medium voltage switchboard, industrial type

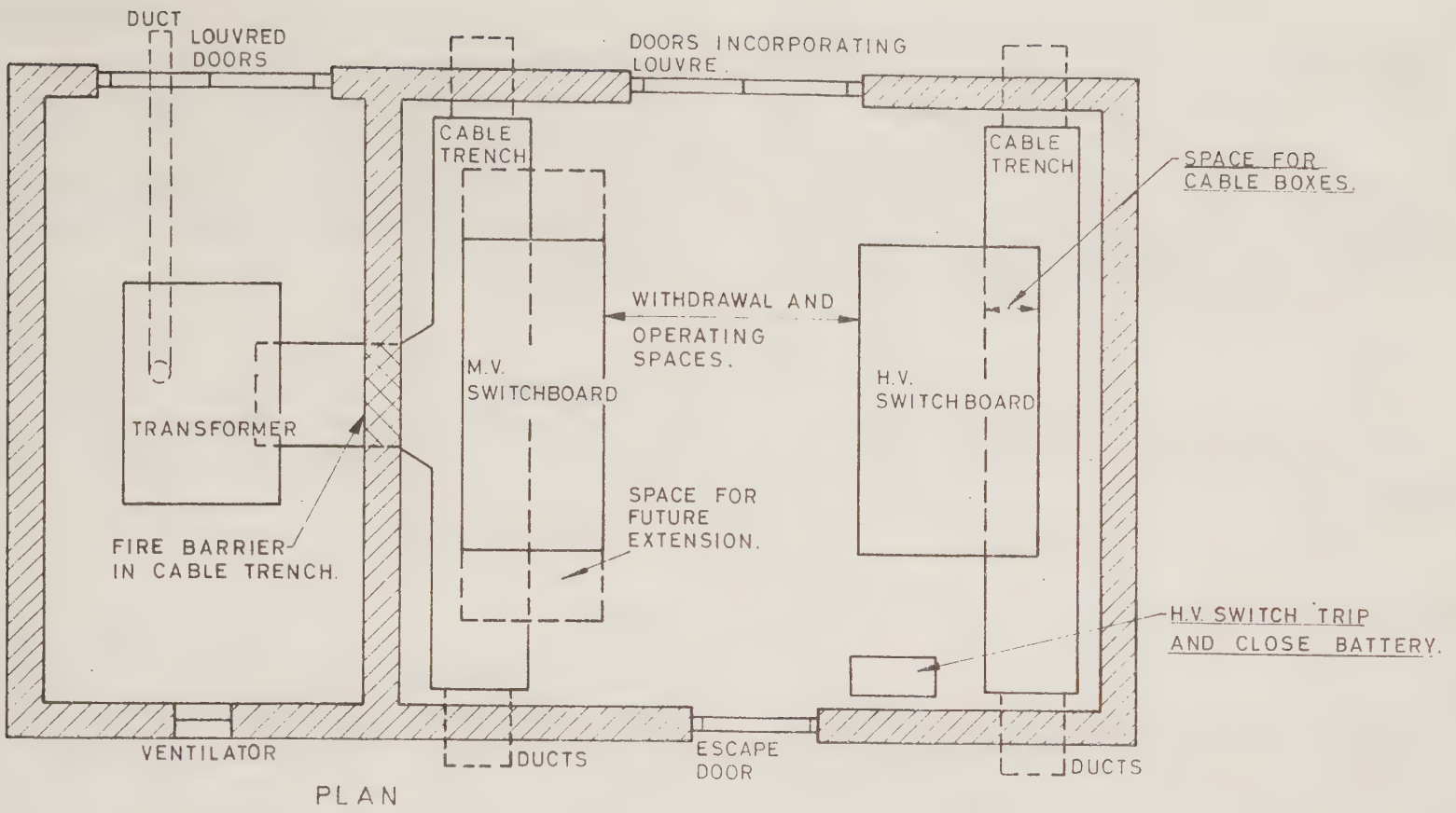


Figure 17 Sub-station with HV ring main switchboard, single transformer and medium voltage switchboard, cubicle type

21. Discharge nozzles should be located at a high level and connected to the release valve by means of steel piping complying with BS1387: galvanised heavy quality type. The spacing of discharge nozzles will depend on the type selected and should be arranged in accordance with the manufacturer's recommendations.

Ventilation

22. Transformer chambers should be adequately ventilated direct to the outer air to prevent excessive temperature rise. Transformer losses are indicated in Table 4 of the main text.

23. Where practicable, the ventilation should be arranged with low level inlet openings on one side of the chamber, and high level openings on the other side or in the roof to ensure good cross-ventilation over the transformer cooling tubes. As a general guide a ratio of 0·1 m^2 of inlet and outlet ventilation openings for each 100 kVA transformer capacity is suggested. It is frequently convenient to provide louvres in the lower part of external doors for the input ventilation, with high level wallmounted louvres or penthouse louvres as outlet ventilation.

24. High voltage switchrooms should also have permanent inlet and outlet ventilation direct to the outer air.

Heating

25. Switchrooms should be provided with thermostatically controlled heating which is capable of maintaining the temperature of the switchroom at not less than 10°C with an outdoor temperature of 0°C. Where electric heating is used, the heaters should be permanently installed and should be of a totally enclosed low temperature type.

Lighting

26. Adequate levels of illumination should be provided in the equipment rooms. The suggested average level of illumination in the high voltage switchroom and transformer chamber is 150 lux. The luminaires in the switchroom should be arranged to give good illumination to the front of the switchboard.

Socket outlets

27. An adequate number of standard 13A mains socket outlets should be provided. Plugs with extra low voltage transformers should be used to supply headlamps (see para. 193 of the main text). Because of the possibility of high fault energies, the circuit should be protected with fuses complying with BS88.

Telephones

28. A telephone with facilities for communication with the local public exchange via the hospital telephone switchboard should be provided in each sub-station.

Warning notices, etc.

29. Conspicious and indelible notices "Danger—High Voltage" should be provided on doors to rooms containing, or on doors giving access to, high voltage equipment. Sub-stations should be identified with number or letter.

30. An indelible notice "CO_2" in 6 inch red letters on a white background should be fixed on the outside of doors giving access to rooms having CO_2 installations in addition to the "Danger—High Voltage" warning notice.

31. A copy of Electricity [Factories Act] Special Regulations 1908 and 1944, and Department of Health and Social Security safety poster together with instructions as to treatment of persons suffering from electric shock should be exhibited in each sub-station (see Hospital Technical Memorandum No. 21—Safety Code for High Voltage Installations). Log books for High Voltage Systems should be provided together with padlocks and keys.

Elimination of piped services

32. The routing of any pipes through switchrooms should be avoided (except the CO_2 installation referred to in paras 16–21).

Appendix 2

Medium Voltage Switchrooms

Siting

1. Switchrooms other than those associated with sub-stations should be sited as close as possible to the load centre and arranged to allow convenient direct entry to rising ducts, horizontal ducts, crawlways, etc.

Layout

2. The layout should allow adequate space around the switchboard for servicing purposes. Suggested minimum clearances between the switchboard and walls are 0·8 m at the rear and 1 m in front, plus additional space required for any withdrawable switchgear. Where provision is made for bus-bars to be extended, adequate space should be allowed at one end of the switchboard for this purpose.

Floor

3. The floors should have a non-slip, dust reducing finish.

Walls

4. As a minimum requirement internal walls should be fair faced brickwork painted to reduce dust formation and facilitate cleaning. Highly flammable wall finishes should be avoided. Walls and doors should be constructed with half hour fire resisting material.

Trenches

5. Under-floor trenches with removable covers will normally be required to accommodate incoming and distribution cables.

Separation of Supplies

6. Where the switchboard consists of two or more main sections, with inter-connection switchgear for emergency use only, the main feeder cables should be kept as far apart as is practicable to eliminate the possibility of a fault on one service affecting the other service cables.

Rubber mats

7. Rubber mats complying with BS921 should be provided along the front of the switchboard.

Heating

8. To reduce the possibility of condensation, medium voltage switchrooms should be provided with thermostatically controlled heating designed to prevent the temperature falling below 10°C with an outdoor temperature of 0°C. Where electric heating is used the heaters should be of totally enclosed low temperature type, rigidly fixed in position, and connected to the supply by permanently installed wiring.

Ventilation

9. The switchroom should be provided with permanent inlet and outlet ventilation direct to the outer air.

Lighting

10. A good standard of illumination should be provided in the medium voltage switchroom. A minimum of 150 lux in the working area is suggested. The luminaires should be arranged to give good illumination of the front of the switchboards.

Socket outlets

11. An adequate number of standard 13A mains socket outlets should be provided. Extra low voltage transformer plugs should be used to supply hand-lamps (see para 193 of the main text). Because of the possibility of high fault energies the circuit should be protected with fuses complying with BS88.

Telephones

12. A telephone with facilities for communication with the local public exchange via the hospital telephone switchboard should be provided in each sub-station.

Marking

13. All switchgear should be clearly and indelibly marked by engraved labels indicating the circuits controlled. Labels marked "DANGER 415 VOLTS" should be provided on panels, etc., giving access to live conductors operating at potentials exceeding 250V.

Wiring diagram

14. A schematic single line diagram, black on white linen print, framed and glazed, should be provided in a conspicuous position in the switchroom to show clearly the function of all switch and fuse-gear. This will assist in clearing faults with the minimum of delay.

Spares, tools, etc.

15. Adequate spare fuses and other essential spare parts, rubber gloves complying with BS697 and any special tools which are liable to be required for emergency use should be provided in a special cabinet or other reserved place.

Electric shock

16. Safety posters together with instructions for the treatment of persons suffering from electric shock should be exhibited in the switchroom.

Elimination of piped services

17. The routing of any pipes through the switchrooms should be avoided.

Appendix 3

Service Ducts

General

1. Duct accommodation should enable the planned services to be installed with adequate clearances and should include space for possible future requirements. As far as is practicable ducts for the accommodation of electrical services should not be used for other services. Where it is necessary to accommodate electrical and other services in the same duct there should be adequate separation between these services and electric cables and conduits. The electrical services should be installed in the upper part of the duct to minimise the possibility of damage from water. When sizing ducts, maintenance facilities should be considered, small ducts are more difficult for servicing and allow less flexibility as regards alterations and additions. Recommended minimum clearances are given in Hospital Technical Memorandum No. 23—Access and Accomodation for Engineering Services.

2. Where bus-bars are installed in ducts with other services they should be totally enclosed, e.g. in steel trunking. "DANGER . . . volts" notices should be provided at points where access to bus-bars can be obtained.

Lift shafts

3. Lift shafts must not be used for the accommodation of rising mains.

Construction

4. Floors for ducts, etc., should be constructed of concrete and have a slight fall and a shallow drainage channel with drainage points at suitable intervals. The sides should be constructed of concrete or brick.

5. Access openings should be large enough to enable standard lengths of conduit (4·5 m approx) to be installed and removed without bending and should be kept clear of conduits and cables. Figure 18 illustrates the principles that should govern the layout of crawlways, subways and service voids.

External cable runs

6. Single cables where installed in open ground should be laid in and covered by sifted soil or sand and protected with reinforced concrete interlocking cover tiles to BS2484. Cover tiles afford adequate protection against hand tools but not against mechanical excavators, they should therefore be used for HV cable runs. For MV cable runs warning tapes should provide an effective or inexpensive alternative. The tapes should be not less than 150 mm wide and 0·1 mm thick, of a suitable colour and bear the legend "electric cable below" or similar in black letters not less than 30 mm high. They should be made of material which is resistant to the acids or alkalis that may be encountered in the ground. Accurately located concrete cable run markers should be provided at internals of approximately 6·5 m where practicable, terminating flush with the surface of the ground.

7. On main cable runs where additional cables may subsequently be required, cable ducts or trenches should be provided. Cable ducts should have spare ways provided to avoid re-excavation.

8. Cable ducts should be used at all points where cables enter buildings and the entry points should be sealed after laying to prevent the passage of moisture and vermin.

9. Cable ducts should also be used where cables pass under roads or other areas having a permanent made-up surface and should be protected with concrete to prevent fracture by traffic. A spare capacity of 25 per cent should be allowed for possible future requirements.

10. Cable ducts should be 90 mm minimum bore. They should be either:

a. earthenware, ceramic glazed internally and of the self aligning type or plastic sleeve type with sealing flange suitably flexible to ensure self alignment of the bore, or

b. fibre with suitable collar joints. Fibre ducts

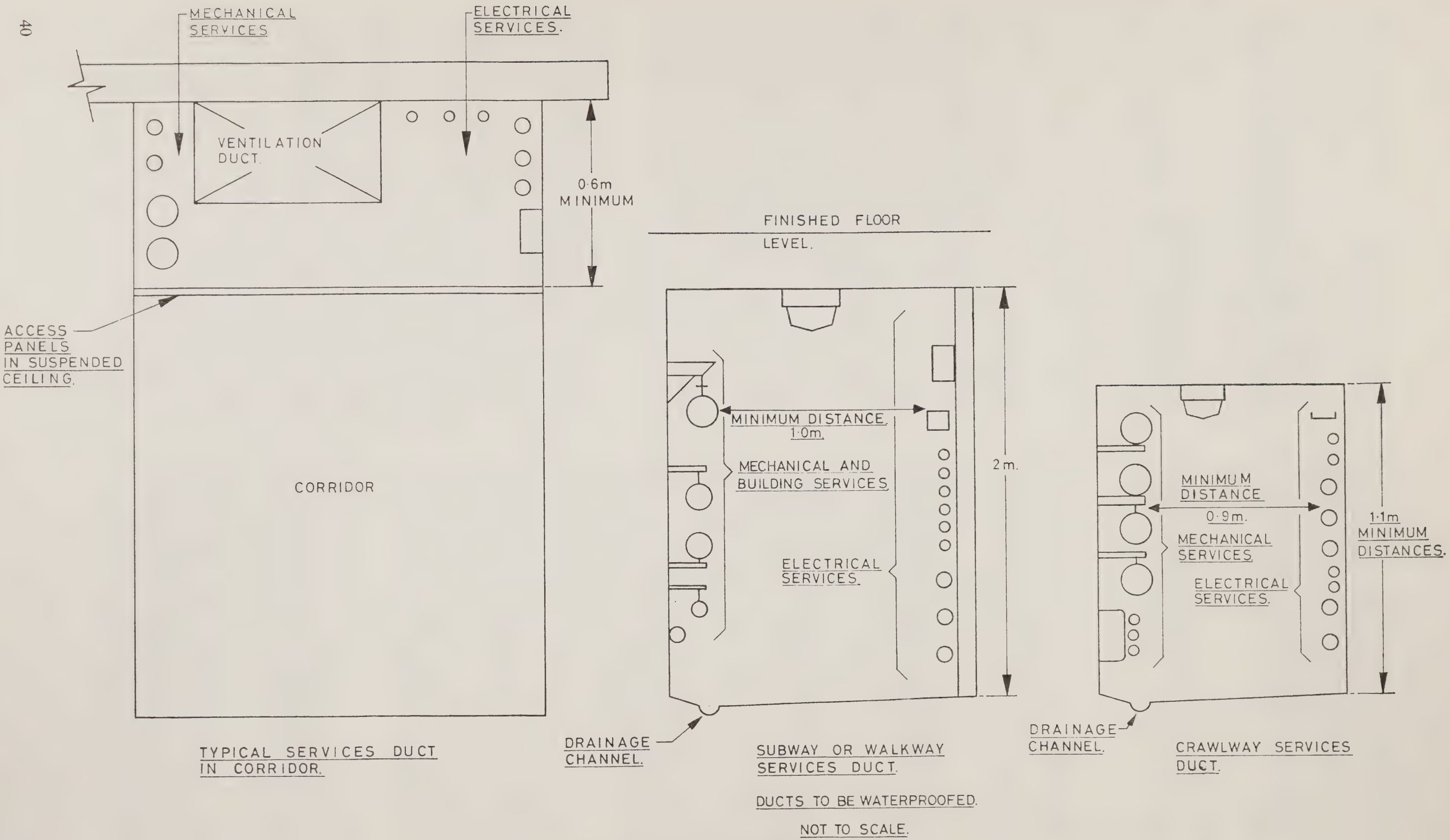


Figure 18 Typical ducts for services

should be laid in and surrounded with concrete to provide a minimum cover of 150 mm above and below and 100 mm on each side of the collars. The concrete should be mixed in the following proportions: Cement 51 kg, fine aggregate 0·78 m^3 in dry loose state or 0.92 m^3 in damp loose state, coarse aggregate 1·84 m^3 (nominal maximum size 35 mm).

11. Before the installation of any cable the alignment of ducts should be proved by using a pull-through fitted with a suitable test piece.

12. Recommended minimum depths for external cable installations are:—

medium voltage cables	0·5 m
high voltage cables	0·8 m

Cable plan

13. A plan (linen print, framed and glazed) showing accurately the position of all external cable runs, cable ducts and trenches, etc., together with all external drainage facilities, should be displayed in a prominent position, in the medium voltage switchroom.

Appendix 4

Lightning Protection Systems

Parts of system

1. A lightning protection system will consist of air terminations, roof conductors, down conductors, bonds to exposed permanent metal parts of the building, testing points, earth terminations and earth electrodes. The installation should be generally in accordance with CP326.

Materials

2. Appropriate copper and copper alloys (BS2870 and BS2874) and aluminium alloys (BS2898) are suitable for air terminations, roof conductors and down conductors. Earth terminations and electrodes should be of copper or copper alloys except that steel cored rods may be used for electrodes.

3. Aluminium is about one third the cost of copper of equivalent size. The risk of corrosion is usually greater with aluminium but can be reduced by taking suitable precautions during installation and it is recommended that aluminium conductors are used for conductors above ground. Aluminium should not be used below ground level.

Zone of protection

4. For practical purposes it can be assumed that a lightning conductor will protect an area below it, equal to a 45° cone with its apex at the highest point of the conductor.

Television aerials

5. Special attention should be given to the protection of television and radio aerials which should be protected by bonding the tubular support of the aerial to the lightning protection system.

Chimneys

6. A non conducting chimney of which the overall width of the top exceeds 1·5 m should have at least two down conductors equally spaced, bonded by a metal cap or by a conductor round the top of the chimney. The use of two down leads will facilitate continuity testing of the down leads. For small chimneys a single unjointed conductor can be used. There are indications that aluminium may be superior to copper or even lead coated copper, in withstanding corrosion when used for air terminations on upper parts of chimneys. Circular rope type conductors have, for the same cross-sectional area, a smaller surface area exposed to corrosion and this type of conductor should be used wherever convenient.

Buildings

7. 20 mm × 3 mm ($\frac{3}{4}$ in. × $\frac{1}{8}$ in.) copper or aluminium roof conductors are suitable. These should be fixed along ridges or around the roof perimeter and interconnected with other conductors run across the roof as necessary, so that no part of the roof is more than 9 m from a conductor. Where there is a higher part of the roof such as a tank or plant room, it should be fitted with a perimeter conductor joined to the main roof system. Aluminium edge trims to roofing systems which have sufficient cross-sectional area and a method of jointing which can be made to conform to the requirements of the Code of Practice, may be used as a roof conductor.

8. Lower buildings which are within the protective cone of higher conductors, e.g. that on a chimney, need not be separately protected.

9. Roof conductors should be fixed e.g. with saddles, at intervals not exceeding 1 m. The fixing should have sufficient clearance around the conductor to allow for movement due to expansion and contraction. Special expansion loops will not normally be necessary.

Air terminations

10. It is not necessary to provide special finials as air terminations. Finials involve additional joints and do not significantly improve the protection afforded by properly installed roof conductors.

Exposed metal parts of structure

11. All metallic projections such as radio and television aerial masts, chimneys, ducts, vent pipes, railings on or above the main surface of the roof should be bonded to parts of the air termination network. Where dissimilar metals are involved there should be complete water-proof protection of the joint (see para. 16) and effective insulation of the conductor, e.g. by pvc covering to prevent any possibility of damp contact between dissimilar metals.

Down conductors

12. Down conductors of 20 mm × 3 mm ($\frac{3}{4}$ in. × $\frac{1}{8}$ in.) copper or aluminium strip are satisfactory. They should follow the most direct route between air terminations and earth terminations and where practicable should run vertically down the outside of the building. Where an external route cannot be followed and it is necessary to run in a vertical duct through the structure, the appropriate requirements of CP326 should be complied with.

13. With down conductors, fixing saddles should be tight and spaced at intervals not exceeding 1 m so that the weight is evenly distributed over the fixings. Exposed metal frames of buildings can be used in place of down conductors where this complies with the specific provision of CP326.

Testing joints

14. Each down conductor should have a test joint in a convenient position but where it cannot be interfered with by unauthorised persons. No connection other than direct to an earth electrode should be made below the test joint. The test clamp should be made of the same metal as the conductor or an alloy of this metal complying with the appropriate British Standard and should incorporate facilities to enable the test conductor to be readily clamped to the down conductor and ensure good electrical contact. Clamping screws should not bear directly on the conductors. Where only one down conductor is provided the connection to the earth electrode can be used for the test point where it is conveniently accessible.

Number of down conductors

15. One down conductor is satisfactory for buildings having a base area less than 100 sq. m or a chimney which is less than 1·5 m across the top. One additional down conductor should be provided for every additional 300 sq. m of the base area or every 30 m of perimeter whichever requires the least number.

Joints and bonds

16. The essential features of satisfactory jointing are:
   a. Adequate mating surface area, not less than 2,500 sq. mm;
   b. Clean surfaces, e.g. with wire wool and clean rag;
   c. Mating surfaces coated with petroleum jelly or other suitable anti-corrosion compound immediately after cleaning. Special anti-corrosion compounds are available for aluminium joints;
   d. High pressure clamping, e.g. by means of bolts or rivets between rigid clamping plates made of a material whose electro-chemical potential is close to that of the conductor material. With aluminium conductors, heavy cadmium or zinc plated steel plates and bolts are suitable;
   e. Complete waterproof protection of joints between dissimilar metals extending at least 75 mm along the conductor on each side of the joint, e.g. an adequate bituminous coating.

Earth terminations and electrodes

17. Each down conductor requires an earth system connected to the lower side of the test joint. The lower the earth resistance the greater the protection.

18. All underground services adjacent to the lightning protection earth termination and having exposed metal in the form of sheathing armouring or piping should be bonded as directly as possible to that earth termination at a point above the test joint.

Earth resistance

19. The resistance to earth of the whole of the lightning protection system should not exceed 10 ohms. Where there is more than one down lead, the resistance of each individual earth termination in ohms should not exceed 10 times the number of earth terminations.

20. A reduction of a resistance to earth below 10 ohms has the advantage of reducing the potential gradient around the earth electrode.

Periodic inspection and testing

21. Lightning protection systems should be inspected and tested at least annually (see CP326). Tests should confirm that the earth resistance does not exceed 10 ohms and that the continuity of down conductors and across any joints in the air termination network is satisfactory.

22. The protection system should be inspected to ensure that it is mechanically sound and free from excessive corrosion and that no structural alterations have been made that affect the system.

Records

23. Records, including "as installed" drawings showing the conductor and earthing systems together with dates of inspections and details of test results and any alterations, should be supplied with other handing over documents (see paras 210 and 215 of the main text).

Appendix 5

Discrimination and Fault Conditions

1. Figure 19 analyses the 3 phase fault levels which may be expected in a typical hospital distribution circuit from the supply authority intake to the power outlet of the final sub-circuit.

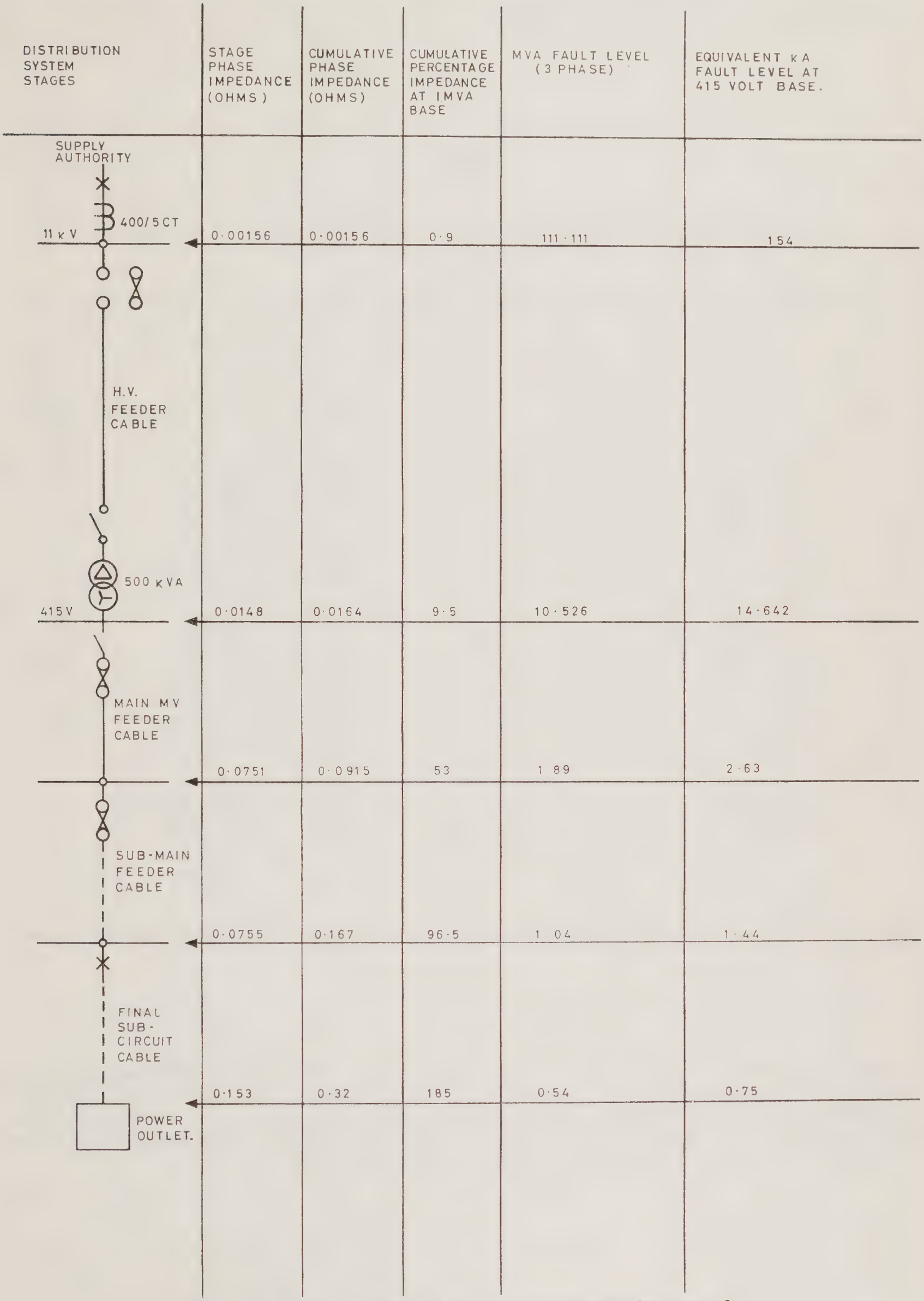


Figure 19 Typical impedances for a hospital distribution network

2. Figure 20 demonstrates how the simplest protection devices can be arranged to provide adequate discrimination, although the curves shown are only typical of the devices which are available. Designers of protection systems should be able to obtain more truly representative curves for specific devices from the manufacturer. The principle of the HV protection system is applicable to the ring or radial HV main distribution systems shown in Figures 3, 4, 7 and 9 of the main text. Discrimination between mcb and fuses is demonstrated. The choice of suitable miniature circuit breakers is referred to in paras 108 and 109 of the main text.

TABLE 7

Summary of fault levels and operating times of the protection devices shown on Figure 20.

Position of fault	Fault level		Operates		Discriminates with	
	KA (415V base)	MVA	Device	Time (secs)	Device	Time (secs)
1	0·75	0·54	100A Mccb	0·3	300A Fuse	>10
2	1·44	1	100A Mccb	0·1	300A Fuse	1
3	1·44	1	300A Fuse	1	500A Fuse	>10
4	2·6	1·9	300A Fuse	0·16	500A Fuse	1·6
5	2·6	1·9	500A Fuse	1·6	50A HV Fuse	>10
6	14·6	10·5	500A Fuse	<0·01	50A HV Fuse	0·02
7	0·75	0·54	30A Mcb	0·01	100A Fuse	0·1
8	1·44	1	30A Mcb	0·01	100A Fuse	<0·01
9	1·44	1	100A Fuse	<0·01	300A Fuse	1·0
10	2·6	1·9	100A Fuse	<0·01	300A Fuse	0·1
11	2·6	1·9	300A Fuse	0·16	50A HV Fuse	>10
12	14·6	10·5	300A Fuse	<0·01	50A HV Fuse	0·02
13	14·6	10·5	50A HV Fuse	0·02	IDMT relay	1
14	100 say	72	50A HV Fuse	<0·01	IDMT relay	0·25
15	154	111	50A HV Fuse	<0·01	IDMT relay	0·2
16	154	111	IDMT relay	0·2	Supply Authority's	—

3. Table 7 analyses the operating time and the discrimination with back-up devices for 3 phase faults at each stage of the typical distribution system. It will be seen that none of the operating times is excessive. Discrimination with back-up devices is adequate except for a fault at point 8, but the 100A back-up fuse was chosen for demonstration purposes only. In practice, a larger fuse (not less than say 160A) would provide adequate discrimination whilst retaining discrimination with the next stage.

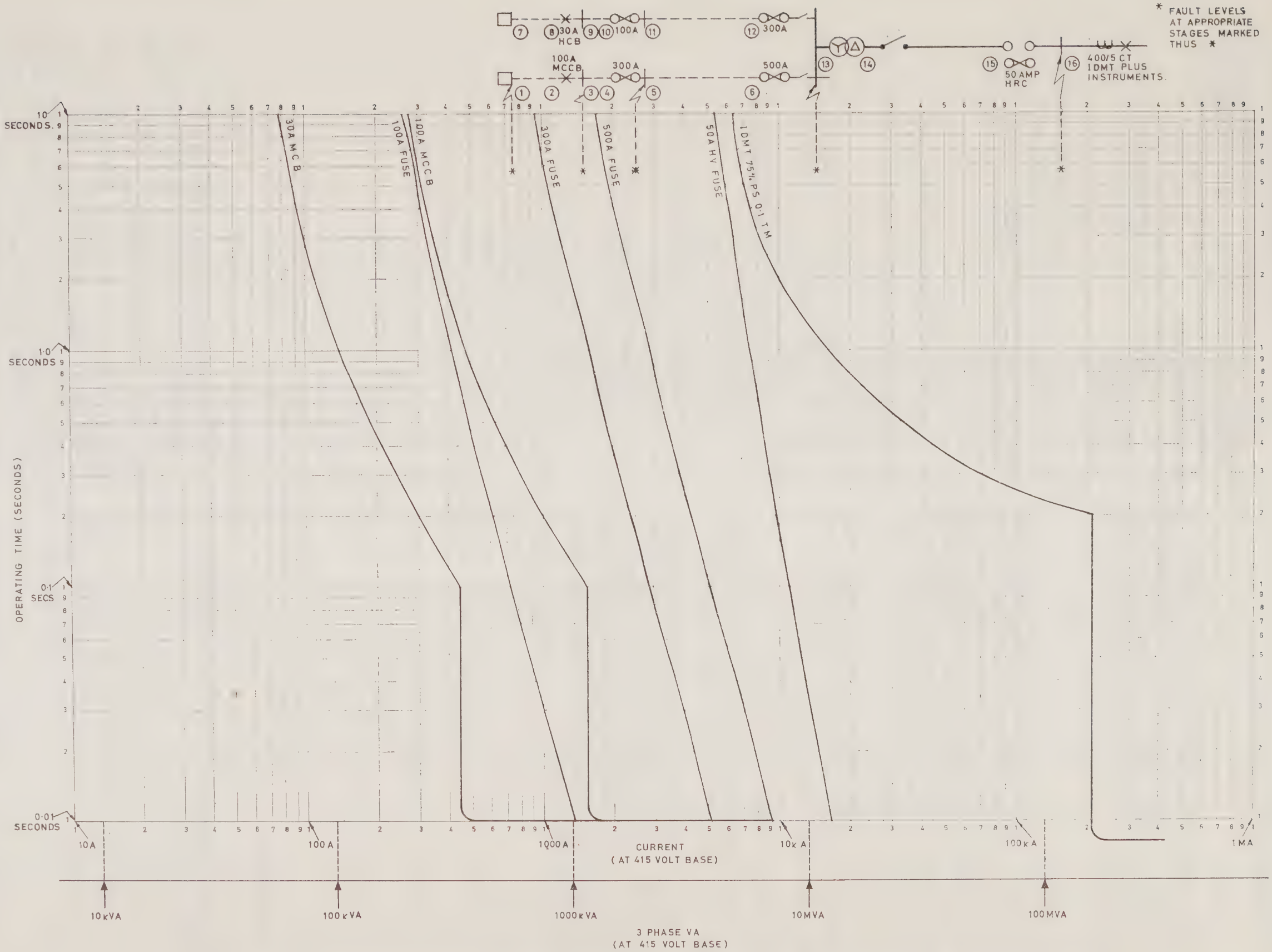


Figure 20 Time-current curves indicating fault levels and operating times at the point shown on Figure 19

Appendix 6

Handling and Disposal of Askarels containing Polychlorinated Biphenyls (PCBs)

1. *General*

Askarels are non-degradable and can accumulate in animals, birds and fish on which they have long-term toxic effects. Assimilation of askarels in sufficient quantity in humans may cause dermatitis, liver damage and jaundice.

2. *Handling*

2.1. Care must be taken to avoid contact of the skin with an askarel, but should it occur the skin must be thoroughly washed with soap and water as soon as possible. Should askarel enter the eyes, wash thoroughly for at least ten minutes and seek medical aid. Should askarel enter the mouth or stomach medical aid must be obtained immediately.

2.2. Protective clothing must be worn when handling an askarel, which should only be undertaken in a well ventilated atmosphere.

3. *Disposal of askarel*

3.1. Disposal of an askarel must be in accordance with the "Deposit of Poisonous Waste Act 1972".

3.2. Collected askarel spillage should be disposed of through approved specialist firms (shown below), who will, where practicable, arrange for collection. Alternatively by arrangement with the firms concerned it should be sent to them in non-leaking drums clearly labelled with their contents.

4. *Scrapping of askarel immersed apparatus*

4.1. Apparatus which is to be scrapped must first be drained and the fluid disposed of as above. This is particularly important if apparatus is to be sold direct to a scrap merchant.

4.2. Alternatively, arrangements may be made for filled apparatus to be sent to an approved specialist disposal firm.

4.3. In such cases written confirmation must be obtained from the firm that they are aware that the apparatus is askarel immersed and that they will dispose of the fluid by high temperature incineration.

5. *Approved specialist disposal contractors*

At the time of issue of this information the following firms have been approved:

a. Disposal of askarel and scrapping of askarel immersed apparatus.

Purle Waste Disposals Ltd.
Claydons Lane, RAYLEIGH
Essex S56 7UW
Telephone: 03742 72211

b. Disposal of askarel only

Dalton & Co. Ltd.
Silkolene Oil Refinery
BELPER
Derby DE5 1WF
Telephone: 077382 2374/7

Appendix 7

Impedance Measurement of Socket Outlets used for Mobile X-ray Units

1. The impedance at socket outlets which will be extensively used for mobile X-ray units up to 300 mA rating should be measured on completion of the installation, using a line to neutral impedance tester.

2. The total source impedance at any socket outlet in a hospital having an installation which complies with the IEE Regulations (see paras 36, 37 and 185 of the main text) can be expected to be less than 0·34 ohm so the full rated output of the mobile X-ray unit will be available. When using socket outlets with lower source impedance it is necessary to add an impedance within the mobile X-ray unit to achieve a total circuit impedance of 0·34 ohms. The mobile X-ray unit impedance correction switch has six steps for this purpose each identified by a number. Socket outlets which are used for mobile X-ray units should be marked with a number from 1 to 6 which could be indelibly marked on a self adhesive label (see para 191 of the main text), indicating the mains impedance at that socket outlet. Table 8 sets out the mains impedance and corresponding number.

TABLE 8

Number marking for socket outlets extensively used for mobile X-ray units.

Indicating Number	Socket outlet line to neutral impedance (ohms)					
1	—	0·01	0·03	0·05	0·07	0·08
2	0·04	0·06	0·08	0·1	0·12	0·13
3	0·09	0·11	0·13	0·15	0·17	0·18
4	0·14	0·16	0·18	0·2	0·22	0·23
5	0·19	0·21	0·23	0·25	0·27	0·28
6	0·24	0·26	0·28	0·3	0·32	0·33
	200V	210V	220V	230V	240V	250V
	Nominal mains voltage at "Consumer Terminals"					

References

British Standards Institution

BS 31: 1940 Steel conduits and fittings for electrical wiring.

BS 37: Part 1: 1952 Electricity meters, general clauses.

BS 37: Part 2: 1969 Watt hour metres single-phase, 2 wire, whole current credit type meters.

BS 37: Part 4: 1954 Polyphase whole current and transformer-operated meters single-phase 3 wire whole current and transformer operating meters. Single-phase 2 wire transformer-operated meters.

BS 37: Part 12: 1974 Watt hour meters, single-phase, multirate, two wire whole current credit type Class 2·0.

BS 77: 1958 Voltages for ac transmission and distribution systems.

BS 88: Part 1: 1975 Cartridge fuses, for voltages up to and including 1000 V ac and 1500 V dc—General requirements.

BS 88: Part 2: 1975 Supplementary requirements for fuses of standardised dimensions and performance for industrial purposes.

BS 89: Part 1: 1970 Single purpose direct acting electrical indicating instruments and their accessories.

BS 116: 1952 Oil circuit-breakers for alternating current systems above 1 kV.

BS 158: 1961 Marking and arrangement of switchgear bus-bars, main connections and small wiring.

BS 159: 1957 Bus-bars and bus-bars connections.

BS 171: 1970 Power transformers.

BS 401: 1931 Steel cylinders for the storage and transport of "liquefiable" gases.

BS 697: 1960 Rubber gloves for electrical purposes.

BS 861: Part 1: 1955 Switches and isolators for voltages not exceeding 660 volts and for currents not exceeding 200 amperes.

BS 861: Part 2: 1972 Switches and isolators for voltages not exceeding 600 volts and currents up to 1200 amperes ac.

BS 921: 1952 Rubber mats for electrical purposes.

BS1361: 1971 Cartridge fuses for ac circuits in domestic and similar premises.

BS1363: 1967 13A plugs, switched and unswitched socket-outlets and boxes.

BS1387: 1967 Steel tubes and tubulars suitable for screwing to BS21 pipe threads.

BS1650: 1971 Capacitors for connection to power-frequency systems.

BS2484: 1961 Cable covers, concrete and earthenware.

BS2631: 1955 Oil switches for alternating current systems.

BS2692: Part 1: 1975	Current limiting fuses.
BS2757: 1956	Classification of insulating materials for electrical machinery and apparatus on the basis of thermal stability in service.
BS2870: 1968	Rolled copper and copper alloys. Sheet, strip and foil.
BS2874: 1969	Copper and copper alloys. Rods and sections (other than forging stock).
BS2898: 1970	Wrought aluminium and aluminium alloys for electrical purposes. Bars, extruded round tube and sections.
BS3535: 1962	Safety isolating transformers for industrial and domestic purposes.
BS3871: Part 1: 1965	Miniature air-break circuit breakers for ac circuits.
BS3871: Part 2: 1966	Moulded case circuit breakers for ac and dc circuits.
BS3938: 1973	Current transformers.
BS4196: 1967	Guide to the selection of methods of measuring noise emitted by machinery.
BS4568: Part 1: 1970	Steel conduit, bends and couplers.
BS4568: Part 2: 1970	Fittings and components.
BS4752: 1971	Circuit breakers of rated voltage up to and including 1000 volts ac and 1200 volts dc.
BS6004: 1975	Pvc-insulated cables (non armoured) for electric power and lighting.
BS6007: 1975	Rubber-insulated cables for electric power and lighting.
BS6207: Part 1: 1969	Mineral-insulated cables. Copper-sheathed cables with copper conductors.
BS6207: Part 2: 1973	Mineral-insulated cables. Aluminium-sheathed cables with copper conductors and aluminium-sheathed cables with aluminium conductors.
BS6346: 1969	Pvc-insulated cables for electricity supply.
BS6480: Part 1: 1969	Lead or lead alloy sheathed cables for working voltages up to and including 33 kV.
BS6899: 1969	Elastomeric insulation and sheath of electric cables.

Codes of practice (Issued by BSI)

CP 326: 1965	The protection of structures against lightning.
CP1010: 1975	Loading guide of oil immersed transformers.
CP1013: 1965	Earthing.

Electricity Council

Standards

35–1	Distribution transformers (from 16 kVA–1000 kVA).
41–5	Indoor Metalclad Switchgear. Ratings up to 250 MVA at 6·6 kV and 350 MVA at 11 kV.

Engineering recommendations

C25/1	Code of Practice on the design of straight through, branch and service joints for use with paper-insulated lead-sheathed cables operating at voltages up to 650 V.
C34	Code of Practice on the design of HV cable joints.

The Institution of Electrical Engineers

Regulations for the Electrical Equipment of Buildings (current edition).

Electrical Research Association

ERA 69–30	Part I	Sustained current ratings for paper-insulated lead-sheathed cables.
	Part III	Sustained current ratings for pvc-insulated cables.

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